EXHIBIT No. 5
PART 1

Date	Plaintiff	BSN	Type
4/29/2003	Nock, E.	0001	Auto
3/10/2009	Bushdorf, A.	0007	Auto
11/9/2009	Herrera, N.	0014	Auto
11/24/2009	Hazard, D.	0023	Auto
5/28/2010	Parkhotyuk, V.	0029	Auto
7/7/2010	Ripley, S.	0040	Auto
7/29/2010	Vogel, A.	0054	Auto
9/24/2010	Thoens, S.	0058	Auto
2/2/2011	Osborne, K.	0069	Auto
3/9/2011	Boutelle, C.	0077	Auto Versus Ped - Death
6/17/2011	Leon-Jenkins, S.	0080	Auto - Supp
5/6/2011	Leon-Jenkins, S.	0081	Auto
6/21/2011	Devonda, F.	0094	Auto
8/1/2011	No, K.	0103	Auto
8/29/2011	Redacted	0114	Auto
9/21/2011	Shim, J.	0125	Auto
9/23/2011	Le, D.	0136	Auto
10/6/2011	Miller, S.	0149	Auto
10/19/2011	Khan, M.	0158	Auto
12/6/2011	Smart, A.	0167	Auto
12/8/2011	Hinds, J.	0177	Auto
1/9/2012	An, S.	0188	Auto
1/10/2012	Corner, U.	0198	Auto
2/3/2012	Baccay, C.	0208	Auto
2/22/2012	LeBaron, S.	0219	Auto
3/7/2012	Stokesberry, P.	0234	Auto
3/16/2012	Zenner, Patrica	0245	Auto
3/26/2012	Nguyen, Thu	0256	Auto
5/21/2012	Torres-Mendoza, Guadalupe	0267	Auto
5/31/2012	Christensen, Lisa	0278	Auto
6/22/2012	Sanders, Charlie	0289	Auto
6/29/2012	LeBlanc, Aimee	0300	Auto
8/24/2012	Green, Valenna	0312	Auto
6/29/2012	Williams, Rachel	0318	Auto
12/18/2012	Williams, Rachel	0328	Auto - Supp
8/8/2012	Sams, Courtney	0331	Auto
8/20/2012	Lee, Justin	0339	Auto
8/24/2012	Green, Valenna	0344	Auto - Duplicate @ 0312
9/6/2012	Dahl, Keri	0350	Auto
9/11/2012	Brumfield, Christopher	0362	Auto
9/20/2012	Allegue, Amber	0374	Auto
9/28/2012	Nettles, Willard	0386	Auto
10/4/2012	Ehringer, Wendy	0396	Auto
10/16/2012	Johnson, Yutta	0408	Auto
2/8/2013	Johnson, Yutta	0418	Auto - Supp
10/19/2012	Lynds, Casey	0421	Auto

11/1/2012	Jones, Clifton	0433	Auto
11/16/2012	Jiminez-Garcia, Alejandro	0444	Auto
11/29/2012	Wu, Zhiping	0456	Auto
1/3/2013	Choi, Doo Sun	0471	Auto
1/22/2013	Tucker, Laura	0484	Auto
1/22/2013	White, Richard	0498	Auto
5/22/2013	Stark, Jasmine	0511	Auto
6/10/2013	Hughes, Rebecca	0520	Auto
6/14/2013	Johnson, Victoria	0532	Auto
6/25/2013	Wolf, Laura	0547	Auto
2/21/2014	Price, Catherine	0560	Auto
6/18/2014	Price, Catherine	0571	Auto - Supp
3/21/2014	Christensen, Mindi	0573	Auto
4/21/2014	Smith, Barbara	0588	Auto
5/19/2014	Barker, Tanisha	0599	Auto
11/24/2014	Wilson, David	0615	Auto
1/16/2015	Ada, Bezhenar	0620	Auto
2/9/2015	Irons, Lonnie	0629	Auto
2/11/2015	Walsh, Daniel E.	0644	Auto
2/19/2015	Rollins, Stephanie	0658	Auto
3/2/2015	Quinn, Dennis	0674	Auto
3/30/2015	Redacted	0686	Auto
4/1/2015	Miller, Mervis	0698	Auto
4/22/2015	Hossein, Elisha	0703	Auto
5/1/2015	Rogers, Karen	0721	Auto
5/18/2015	Ake, Cari	0727	Auto
7/22/2015	Swanson, Lloyd Jr.	0734	Auto
8/13/2015	Pristupa, Irina	0746	Auto
8/28/2015	Redacted	0754	Auto
9/21/2015	Scott, Walter	0757	Auto
9/22/2015	Pomeroy, Jane	0769	Auto
11/17/2015	Gaines, Emancia	0781	Auto
12/1/2015	Redacted	0794	Auto
12/11/2015	Lear, Douglas & Joie	0810	Auto
1/5/2016	Pak-Byeon, Hanna	0825	Auto
2/5/2016	Pak-Byeon, Hanna	0836	Auto - Supp
1/8/2016	Dupart, Kirsten	0839	Auto
1/26/2016	Mekhael, Refaat	0852	Auto
2/25/2016	Ung, Chhung Hang & Keang Ly Tang	0865	Auto
3/8/2016	Redacted	0879	Auto
3/10/2016	Dworzky, Tina	0892	Auto
3/11/2016	Clevenger, Tauni	0906	Auto
3/16/2016	Redacted	0919	Auto
4/18/2016	Whitaker, Aaron	0929	Auto
5/24/2016	Wisdom, Leslie	0942	Auto
6/3/2016	Trice-Allen, Sandra	0955	Auto
6/6/2016	Redacted	0970	Auto

6/10/2016	Mekhael, Refaat & Ledia	0985	Auto
6/14/2016	Olsen, Jessica	1000	Auto
9/28/2017	Olsen, Jessica	1011	Auto - Supp
6/28/2016	Redacted	1014	Auto
8/10/2016	O'Brien, Joell	1025	Auto
8/15/2016	Redacted	1036	Auto
9/8/2016	Miller, Jasmin & Meilin Lani	1050	Auto
9/16/2016	Sell, Kristi	1061	Auto
11/14/2016	Phillips, Christine	1073	Auto
11/28/2016	Mitchell, Carolyn	1086	Auto
2/8/2017	Dominguez, Vicki	1098	Auto
3/10/2017	Ngo, Vuong	1115	Auto
5/12/2017	LaParne, Judith	1123	Auto
5/12/2017	Butchart, Debbie Joe	1135	Auto
6/19/2017	Rodriguez-Ramirez, Maria	1142	Auto
7/10/2017	Redacted	1154	Auto
9/5/2017	Redacted	1161	Ped Versus Cement Chute and M
9/7/2017	Grundl, Gregory & Tamieka	1172	Med Mal - Chiro Injury
1/8/2018	Wong, Elizabeth	1175	Auto
1/12/2018	Turner, Deborah	1186	Auto
2/13/2018	Kamholz, Larry & All Savers Ins. Co.	1201	Auto
3/1/2018	Chicas, Estella	1211	Auto
3/28/2018	Herrera, Juan	1223	Auto
6/14/2018	Mondragon, Sandy	1237	Auto
6/15/2018	Willis, Eric	1253	Auto
6/22/2018	Hwang, Seon Kyu	1265	Auto
7/9/2018	Smith, Pamela	1272	Auto
8/14/2018	Smith, Pamela	1283	Auto - Supp
7/12/2018	Chalal, Amelie	1284	Auto
8/17/2018	Hollingshead, Barbara	1321	Trip and Fall
9/13/2018	LaCourse, Amber	1330	Auto
10/5/2018	Prescott, Patricia	1339	Auto

ARCCA, INCORPORATED
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EXHIBIT
Probst 1
5-23-17 MY

April 29, 2003

Michael B. Oropollo, Esquire
Harwood Lloyd, LLC
130 Main Street
Hackensack, New Jersey 07601

Re: *Eileen Nock and Frank Nock vs. David Costanzo and Cambridge Allen & Associates, Inc.*
Docket No.: SOM-L-613-01
Claim No.: 011001357-022
ARCCA File No.: 2176-002

Dear Mr. Oropollo:

Thank you for the opportunity to participate with you in the above-referenced matter. ARCCA was retained to evaluate the subject incident in relation to Eileen Nock's claimed injuries. This preliminary analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to revise or supplement this preliminary report if additional information becomes available.

The opinions given in this report are based on my analysis of the materials available and Ms. Nock's claimed injuries, using scientific and engineering methodologies generally accepted in the automotive industry. The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of both the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

<u>Incident Description:</u>

According to the New Jersey Police Accident Report (PAR), on July 28, 2000, Eileen Nock was driving a 1989 Cadillac Eldorado westbound on Route 22 in Mountainside, New Jersey. David Costanzo was operating a 1997 Ford Taurus directly behind the Nock vehicle. The Costanzo

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vehicle was unable to stop in time and contacted the rear of the Nock vehicle. Both vehicles were driven from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- New Jersey Police Accident Report, July 28, 2000
- Medical records pertaining to Eileen Nock
- Plaintiff's Answers to Form A Interrogatories
- Transcript of deposition of David Costanzo, January 7, 2003
- Transcript of deposition of Eileen Nock, January 3, 2002
- Transcript of deposition of Eileen and Frank Nock, July 11, 1994 (previous incident)
- Answers to General Motor Vehicle and Personal Injury Interrogatories (previous incident)
- Transcript of Trial for State of New Jersey v. Sumit Sachdeva (previous incident)
- New Jersey Police Accident Report, December 29, 1991 (previous incident)
- Medical records pertaining to Eileen Nock from previous incident
- Six (6) color photographs of the subject Cadillac Eldorado
- Hub Appraisal Service, Inc. vehicle damage appraisal report for the subject Cadillac Eldorado, August 24, 2000
- George Olmezer Appraisal Service Inc. repair estimate for the subject Cadillac Eldorado, assessed by Dominick Plastina, August 12, 2000
- VinPower3 and Expert AutoStats data sheets for the subject Cadillac Eldorado
- VinPower3 and Expert AutoStats data sheets for the Ford Taurus
- Insurance Institute for Highway Safety report of Low Speed Crash Tests for a 1996 Ford Taurus
- ARCCA inspection of an exemplar 1988 Oldsmobile Toronado

Claimed Injuries of Eileen Nock:

According to her Answers to Interrogatories and medical records, Ms. Nock is claiming the following injuries as a result of the subject incident:

- Cervical spondylosis at C4-C5 and C5-C6
- Right lateral disc herniation at L4-S1
- Disc bulge at L4-L5

Vehicle Damage and Accident Severity:

There was no reported damage to the Costanzo Taurus. The Insurance Institute for Highway Safety (IIHS) tested a comparable Ford Taurus in a series of five mile-per-hour frontal impacts; generating a-cost of repair of up to $756 for a single frontal impact. The complete lack of damage to the subject vehicle indicates that there would have to be more damage to the Costanzo Ford Taurus necessitating additional repairs or parts in order to equal the IIHS testing. This lack of additional repairs or parts is indicative of an impact of less than five miles-per-hour.

The damage to the Nock Cadillac Eldorado was limited to minor cosmetic damage. There was no reported damage to the structure or any safety element of the subject Eldorado. The only significant damage noted was displacement of trim pieces on the lower rear quarter panels. This occurred due to stroking of the rear bumper shock isolators that allowed for forward motion of the rear bumper. Any damage was minor enough that the vehicle was capable of being driven from the incident scene.

A typical bumper system consists of a fascia, bumper beam, and an impact absorber. The Nock vehicle's rear bumper was equipped with shock isolators. The shock isolator acts as a shock absorber between the bumper and the structure of the vehicle. Compression testing of an exemplar Cadillac Eldorado rear-bumper isolator was performed. The bumper isolator is an energy absorbing device between the bumper and the structure of the vehicle. It is designed to compress and allow for displacement of the bumper relative to the vehicle. After the load is removed, the bumper should return to its original position if the limit of the isolator was not exceeded. Testing indicated that one would expect damage to the structure of the subject Eldorado once the accelerations exceeded 0.5 Gs, based upon the published weight of the subject Eldorado. Based upon testing and reported damage to the subject Eldorado, the acceleration of the subject Eldorado and Ms. Nock was at or below 0.5 Gs.

The acceleration experienced due to gravity is 1G. This means that Ms. Nock's body experiences 1G of loading while in a sedentary state. Therefore, Ms. Nock experiences an essentially equivalent acceleration on a daily basis while in a sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Nock in her daily life would have increased the loading to her body beyond the sedentary 1G. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces[1]. More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, due to the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Review of the damage, incident data, testing, published literature, and my experience indicates an incident resulting in a delta-V below five miles-per-hour (the delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). This incident, and

[1] Mow, Van C. and Hayes, Wilson C., Basic Orthopaedic Biomechanics, Raven Press, 1991, New York

the resulting contact, would result in minimal accelerations to the subject Eldorado and its occupant.

Findings:

1. On July 28, 2000, Eileen Nock was driving the subject 1989 Cadillac Eldorado when a 1996 Ford Taurus contacted it from the rear at a low speed.
2. There was no reported damage to any structural elements of either the subject Cadillac Eldorado or Ford Taurus.
3. The lack of damage to the both vehicles is consistent with a delta-V below, five miles-per-hour with negligible resultant accelerations for the subject Eldorado and Ms. Nock.

Kinematic Analysis:

Ms. Nock's medical records indicate that, at the time of the subject incident, she was 52 years of age, was 61 inches in height, and weighed approximately 150 pounds. According to her medical records, Ms. Nock was wearing the available lap and shoulder belt

According to the laws of physics, when the Ford Taurus contacted the subject Eldorado, had there been enough energy transferred to cause any motion, the Eldorado would have been pushed forward. This would have resulted in the vehicle moving forward relative to Ms. Nock, causing her body to load into the seat and seat back structure, thus coupling her motion to the accelerating vehicle. This process would have resulted in a rearward motion of her body relative to the interior of the vehicle. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back. Certainly any minor forward motion was well within the range of protection afforded by the available restraint system.

It is well known that minimal head accelerations occur in everyday life and do not produce injuries. Sneezing can cause momentary accelerations of the head of around 3Gs. In amusement park bumper cars, with occupant dynamics more severe than the subject incident, accelerations beyond those in the subject incident are routinely tolerated[2]. A study by Allen, et al., on the acceleration of daily perturbations reveals multiple events that are capable of producing rearward accelerations of the head in excess of the accelerations of the subject incident. A cough, slap on the back, hopping off of a 20 cm step onto both feet, and plopping passively backward into a low-backed seat, all produce peak rearward head accelerations in excess of 2.3 Gs[3]. Even the simple act of controlled sitting from a standing position produces an acceleration of 1.6 Gs. Rosenbluth and Hicks indicated in a study that the rear acceleration of the head during rope-

[2] Siegmund, G.P., Williamson, P.B., *"Speed Change (delta-V) of Amusement Park Bumper Car"*, Proceedings of the Canadian Multidisciplinary Road Safety Conference VII

[3] Allen, M.E., Weir-Jones, I., Motiuk, D.R., Flewin, K.R., Goring, R.D., Kobetitch, R., and Broadhurst, A., *"Acceleration Perturbations of Daily Living: A Comparison to 'Whiplash'"*, Spine, Volume 19, Number 11, pp 1285-1290, 1994

skipping is 3.5 Gs[4]. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Discussion:

Based upon the review of the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Nock was well within the limits of human tolerance. Without exceeding the limits of human tolerance or the normal range of motion there is no injury mechanism present to causally link Ms. Nock's reported injuries and the subject incident.

The only area possibly exposed to unsupported motion in such an incident in a normal vehicle is the head/neck complex. This usually occurs when the head hyper-extends over the headrest of the seat. Examination of an exemplar 1988 Oldsmobile Toronado, a sister vehicle of the Eldorado, which is the same based upon year/model interchange, showed that the nominal seat back height with an unoccupied, uncompressed seat is 28 inches with the headrest in the full down position, as positioned as Ms. Nock described. An anthropometric regression, based upon Ms. Nock's age, height, and weight, places her seated height at approximately 31.3 inches. In order for a headrest to prevent an occupant from hyper-extending over it, it does not need to be at the full seated height of the occupant, but rather needs to support up to approximately the ear level, or just above the base of the skull. This is due to the center of rotation of the head. Thus, the seat in the subject Eldorado was high enough to have prevented Ms. Nock's head from extending over it in this collision, even with the headrest in the full down position. One would not expect to see anything more than minor transient neck stiffness and soreness due to the minor nature of this incident.

In a rear impact, the thoracic and lumbar spine of an occupant is well supported by the seat and seat back. This prevents any adverse motions or loading of the thoracic or lumbar spine. There was no mechanism present in this incident to account for the thoracic or lumbar injuries or aggravation of pre-existing conditions to Ms. Nock. The seat back would not allow for hyper-extension of the thoracic or lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless a lower portion of the spine is supported with the upper portion unsupported. As stated previously, Ms. Nock's thoracic and lumbar spine area was well supported and, as such, one would only expect slight extension as the shoulders moved rearward towards the seatback. There was no mechanism present in this incident to account for the claimed back injuries to Ms. Nock. A mechanism would only be present if relative motion of the individual vertebrae existed in the subject incident. This means that a vertebra is moving in a different direction relative to its neighbor. Only with relative motion is loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur. Finally, Ms. Nock has an extensive history of back pain as noted in the provided medical records that antedates the subject incident.

4 *"Evaluating Low-Speed Rear-End Impact Severity and Resultant Occupant Stress Parameters"*, J Forensic Sci 1994;39:1393-1424

ARCCA

Conclusions:

Based upon a reasonable degree of biomedical engineering certainty, I conclude the following:

1. On July 28, 2000, Eileen Nock was the driver of a 1989 Cadillac Eldorado which was contacted in the rear by a 1996 Ford Taurus driven by David Costanzo.
2. The contact resulted in minor, tolerable vehicle accelerations at or below 0.5 Gs, with a change in velocity below five miles-per-hour.
3. If any of the crash forces were beyond the level of muscle reaction they would have resulted in a slightly rearward motion of Ms. Nock's body relative to the interior of her vehicle.
4. Ms. Nock's cervical spine would have been protected with support by her head restraint. One would not expect hyper-extension of his head and neck due to the minor nature of the subject incident. While minor transient neck pain can certainly occur in a rear-end collision, it is unlikely that it would have required any medical attention and would have resolved itself in a relatively short time.
5. There was no injury mechanism present to account for Ms. Nock's claimed back injuries. Ms. Nock's back was protected and well supported by the seat and seat back.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/gj

EXHIBIT
Probst 2
5-23-17 VhF

ARCCA, INCORPORATED
4314 ROOSEVELT WAY NE
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March 10, 2009

Eric S. Newman, Esquire
McDermott Newman
1001 Fourth Avenue, Suite 3200
Seattle, WA 98154

Re: *Bushdorf v. Carr*
ARCCA Case No.: 3465-003

Dear Mr. Newman:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the claimed injuries of Andrea Bushdorf. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available and the claimed injuries of Ms. Bushdorf, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of both the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

Incident Description:

According to the State of Washington Police Traffic Collision Report, on March 6, 2006, Andrea Bushdorf was the driver of a 1997 Ford Probe traveling west on NE 54th Street near the intersection of Ravenna Avenue NE in Seattle, Washington. Regina Carr was the driver of a 1994 Saturn SW2 traveling south on Ravenna Avenue NE at the intersection of NE 54th Street. As the incident Saturn entered the intersection, the right front corner of the Saturn contacted the right rear of the subject Ford Probe. No airbags deployed in either vehicle and neither vehicle required towing.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, March 6, 2006
- Deposition of Andrea Bushdorf, December 3, 2008
- Five (5) color reproductions of photographs of the subject Ford Probe
- Roosevelt Auto Body, Inc. University Estimate Report for the subject Ford Probe, written by Chris Cheuvront, April 4, 2006
- VinPower and Expert AutoStats data sheets for the subject Ford Probe
- VinPower and Expert AutoStats data sheets for the incident Saturn SW2

Claimed Injuries of Andrea Bushdorf:

According to the provided documents, Ms. Bushdorf is claiming the following injuries as a result of the subject incident:

- Whiplash
- Soft tissue injury to her shoulder
- Soft tissue injury to her back

Damage and Incident Severity:

The damage to the vehicles was assessed with the photographs and the repair estimate. The damage to the both vehicles was limited to cosmetic damage; there was no reported structural damage.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[4,5,6,7,8] Photographic analyses of the provided photographs of both vehicles revealed the damage due to the subject incident.

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4 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

5 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

6 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

7 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

The reported events and the minimal damage to the subject vehicle indicate that this incident was consistent with a sideswipe. A sideswipe is defined as vehicular contact in which the surface of one vehicle slides against another vehicle or object. In a sideswipe, the two contact surfaces do not necessarily achieve a common velocity. Therefore, common approaches for calculating the change in velocity do not readily apply. There was no snagging or engagement to either vehicle in this incident, as is apparent by the limited surface damage noted in the photographs and repair estimate. A snag may be recognized as a point of deformation that is deformed rearward or forward. The effective acceleration of a sideswipe of the nature such as this incident is a nominal 1g.[9,10]

The damage to the vehicle in the subject incident is consistent with a collision calculated to result in a Delta-V of 2.3 mile per hour, assuming an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms). The Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post impact velocity. The above analyses are consistent with numerous staged low-speed impact tests that indicate that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[11] Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in limited change in velocity. By the laws of physics, the calculated acceleration and Delta-V was the maximum experienced by the subject Ford Probe in which Ms. Bushdorf was seated.

The acceleration experienced due to gravity is 1g. This means that the body of Ms. Bushdorf experiences 1g of loading while in a sedentary state. Therefore, she experiences a greater equivalent acceleration on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[12] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

It is well known that minimal head accelerations occur in everyday life and do not produce injuries. Sneezing can cause momentary accelerations of the head of approximately 3g. A study by Allen, et al., on the acceleration of daily perturbations reveals multiple events that are capable of producing rearward accelerations of the head in excess of the accelerations of the subject incident. A cough, slap on the back, a hop off of a 20-centimeter step onto both feet, or a passive drop backward into a low-backed seat all produce peak rearward head accelerations in excess of 2.3g.[13] Even the simple act of controlled sitting from a standing position produces an acceleration of 1.6g. Rosenbluth and Hicks indicated in a study that the rear acceleration of the head during

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9 Bailey, M. N., B. C. Wong, et al. (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

10 Toor, A., E. Roenitz, et al. (1999). Practical Analysis Technique for Quantifying Sideswipe Collisions (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

11 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

12 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

13 Allen, M. E., I. Weir-Jones, et al. (1994). "Acceleration Perturbations of Daily Living." Spine 19(11): 1285-1290.

rope-skipping is 3.5g.[14] As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Findings:

1. On March 6, 2006, Ms. Bushdorf was the belted driver of a 1997 Ford Probe which was contacted in the right rear by a 1994 Saturn SW2.
2. The incident is consistent with contact resulting in a change in velocity of 2.3 miles per hour, with nominal accelerations of 1g for the Ford Probe in which Ms. Bushdorf was seated.
3. The acceleration experienced by Ms. Bushdorf was within the limits of human tolerance and the personal tolerance levels of Ms. Bushdorf based on an engineering analysis of her reported physical activities, and were comparable to that experienced during various daily activities.

Kinematic Analysis:

According to the laws of physics, when contact between the Ford Probe and the Saturn SW2 occurred, had there been enough energy transferred to cause any motion; the Ford would have been decelerated and pushed leftward. This would have resulted in the vehicle slowing and moving leftward relative to Ms. Bushdorf, causing her body move forward and rightward. Any motion would have been within the range of protection afforded by the available restraint system.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Bushdorf was well within the limits of human tolerance, Ms. Bushdorf's personal tolerance limits, and well below the acceleration levels that Ms. Bushdorf likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Ms. Bushdorf's reported injuries and the subject incident.[15,16]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied

[14] Rosenbluth, W. and L. Hicks (1994). "Evaluating Low-Speed Rear-End Impact Severity and Resultant Occupant Stress Parameters." Journal of Forensic Science 39: 1393-1424.

[15] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[16] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament - a thick tough, fibrous tissue that connects bones together - by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type of injury to any tissue, significant motion, which produces stretching, must occur.

In recent papers by Ng et al.,[17,18] accelerations of the lumbar spine were measured during activities of daily living, and peak accelerations were measured to be an average 5.09g for small females (averaging 1.58 meters in height) and average 4.24g for mid females (averaging 1.65 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 7g. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender). As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. The accelerations of the head were also measured during activities of daily living, and peak accelerations were measured to be an average 2.79g for sitting quickly in a chair. The measured head accelerations were 8.08g for a vertical leap. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[19]

There is no reason to assume that the claimed neck injury is causally related to the subject incident. "Whiplash" is generally associated with rear impacts and hyperextension of the cervical spine. There was no hyperextension mechanism present in the subject impact, there would only be slight forward and rightward bending. The cervical spine is extremely tolerant to inertial loading which results in flexion and lateral bending. A simple explanation for this is that the body has a built-in head restraint. The head is limited in flexion by contact of the chin to the chest. Live human subjects have regularly been exposed to g levels up to approximately 16g for forward flexion and 9g for lateral bending with no acute trauma, only transient, short term soreness.[20] The subject incident had maximum accelerations of 1g. Ms. Bushdorf would not have been exposed to any loading or motion outside of the range of human tolerance. There was no injury mechanism present in the subject incident to account for Ms. Bushdorf's claimed cervical injuries. As stated previously, Ms. Bushdorf regularly receives loading that exceeds the acceleration to her body in

[17] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

[18] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

[19] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

[20] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

the subject incident. The cervical spine is extremely tolerant to inertial loading which results in flexion and/or lateral bending. A simple explanation for this is that the body has a built-in head restraint. The head is limited in lateral bending by contact of the chin to the chest and/or shoulders.[21]

There is no reason to assume that the claimed thoracic or lumbar spine injury is causally related to the subject incident. The magnitude and direction of the force due to contact between the two vehicles was insufficient to have produced an injury mechanism. As stated previously, Ms. Bushdorf regularly receives loading that exceeds the acceleration to her body in the subject incident.

In the subject incident there would also be no extension or lateral bending of Ms. Bushdorf's upper torso outside the normal range of motion. There is no causal relationship between the claimed back injuries of Ms. Bushdorf and the subject incident; there was no injury mechanism present. One would only expect slight flexion and lateral bending as the shoulders moved forward and rightward. It should be noted that this motion is limited by the restraint system. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. An example of this is when one vertebra is moving in a different direction relative to its neighbor. Only with relative motion is loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur. Once again, the motion and loading to the thoracic and lumbar spine of Ms. Bushdorf was less than that of the simple act of touching one's toes.

There is no reason to assume that the claimed shoulder injury is causally related to the subject incident. The magnitude and direction of the force due to contact between the two vehicles was insufficient to have produced an injury mechanism. As stated previously, Ms. Bushdorf would tend to move forward and rightward, this would move her shoulders away from any rigid interior object in her vehicle. There would be no mechanism for a direct contact injury. Additionally, the magnitude of force is insufficient to produce an inertial injury.

Conclusions:

Based upon a reasonable degree of biomedical engineering certainty, I conclude the following:

1. On March 6, 2006, Ms. Bushdorf was the belted driver of a 1997 Ford Probe when it was contacted in the right rear by a Saturn SW2.
2. The contact between the vehicles is consistent with a side swipe.
3. The change in velocity was 2.3 mile per hour with accelerations of a nominal 1g.
4. The acceleration experienced by Ms. Bushdorf was within the limits of human tolerance and the personal tolerance levels of Ms. Bushdorf based on an engineering analysis experienced during various daily activities.

[21] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

5. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a slightly forward and rightward motion of Ms. Bushdorf's body relative to the interior of the Ford Probe. Any motion would have been well within the protective realm of the available restraint system and the normal range of motion and tolerance levels of Ms. Bushdorf.
6. There is no causal link between the reported cervical spine injuries of Ms. Bushdorf and this reported collision. Ms. Bushdorf experiences loading on a daily basis greater than that experienced in this incident.
7. There is no causal link between the reported back injuries of Ms. Bushdorf and this reported collision. Ms. Bushdorf's thoracic or lumbar spine experience loading on a daily basis greater than that experienced in this incident.
8. Both the magnitude and direction of force were insufficient to produce an injury mechanism for the shoulder injury for Ms. Bushdorf and this reported collision.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
Probst 3
5-23-17

November 9, 2009

Marc Meigs, Esquire
Law Offices of John F. Adlard
1221 SW Yamhill Street, Suite 250
Portland, OR 97205

Re: *Herrera, Nidia v. Judith Wilson*
Washington County Circuit Court Case No. C09 1658CV
ARCCA Case No.: 3240-047

Dear Mr. Meigs:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Nidia Herrera. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the American Society of Safety Engineers, the American Society of Mechanical Engineers and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez, M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques. (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

ARCCA

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the subject incident, therefore a police incident report for the subject incident is not available. The following incident description is based upon the reviewed documents. On July 16, 2008, Nidia Herrera was the belted driver of a 2002 Chevrolet Tracker stopped for a traffic signal in Middleton, Washington. Judith Wilson was the driver of a 2003 Suzuki XL 7 behind the subject Chevrolet. When the traffic signal changed to green, Ms. Wilson proceeded forward, however the Herrera vehicle did not. The front of the incident Suzuki contacted the rear of the subject Chevrolet. No airbags in either vehicle deployed and neither vehicle required towing from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Medical records of Nidia Herrera
- Nineteen (19) color reproductions of photographs of the subject Chevrolet Tracker
- Six (6) color reproductions of photographs of the incident Suzuki XL-7
- Deposition transcript of Nidia Herrera, September 4, 2009
- Plaintiff's Response To Defendant's First Request For Production Of Documents
- Artistic Auto Body, Inc. Preliminary Estimate written by Brandon Kittrell, October 9, 2008
- GEICO Estimate of Record for the incident Suzuki XL-7, written by Patrick Nguyen, July 24, 2008
- VinPower and Expert AutoStats data sheets for the subject Chevrolet Tracker
- VinPower and Expert AutoStats data sheets for the incident Suzuki XL-7

Injury Summary:

According to the documents, Ms. Herrera is claiming the following injuries as a result of the subject incident:

- Cervical sprain/strain
- Thoracic sprain/strain
- Lumbar sprain/strain
- Left foot sprain/strain
- Left wrist sprain/strain

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Damage and Incident Severity:

The photographs of the vehicles, and repair estimates were utilized in analyzing the incident severity. There was no noted damage to the incident Suzuki XL-7. There was cosmetic damage to the rear bumper of the subject Chevrolet Tracker.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[4,5,6,7,8] The damage to the subject Chevrolet Tracker, as defined by the photographic reproductions and the repair estimate, was used to perform a damage threshold speed change analysis.[9] The Insurance Institute for Highway Safety (IIHS) performs low speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 1999 Chevrolet Tracker, essentially the same vehicle as the 2002 Chevrolet Tracker, in a series of 5 mile-per-hour impacts. In a 5 mile-per-hour rear impact into a flat barrier, the test Chevrolet sustained damage such that the rear-mounted spare tire intruded into the rear of the vehicle and crushed the back door and shattered the fixed rear glass. The rear-mounted spare tire carrier, rear door interior trim panel, body sill plate and rear door striker plate were also damaged. The damage sustained by the Chevrolet in the IIHS rear impact testing is greater than the damage sustained by the incident Chevrolet in the subject incident. This places the subject incident speed below the test speed of 5 miles per hour.

The above damage-threshold-speed-change analysis is consistent with numerous staged low-speed impact tests that indicate that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[10] Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of below 5 miles per hour. Using an acceleration pulse with the shape of a haversine, and a duration of impact of 200 milliseconds, the maximum acceleration associated with a 5-mile-per-hour impact is 2.3g. By the laws of physics, this acceleration was greater than the maximum acceleration experienced by the subject Chevrolet Tracker in which Ms. Herrera was seated.

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4 Campbell, K.L. (1974) Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

5 Day, T.D. and Siddall, D.E. (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

6 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

7 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

9 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

10 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

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The acceleration experienced due to gravity is 1g. This means that Ms. Herrera experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[11] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 2.3g associated with the subject incident.[12]

It is well known that minimal head accelerations occur in everyday life and do not produce injuries. Sneezing can cause momentary accelerations of the head of approximately 3g. A study by Allen, et al., on the acceleration of daily perturbations reveals multiple events that are capable of producing rearward accelerations of the head in excess of the accelerations of the subject incident. A cough, slap on the back, a hop off of a 20-centimeter step onto both feet, or a passive drop backward into a low-backed seat all produce peak rearward head accelerations in excess of 2.3g.[13] Even the simple act of controlled sitting from a standing position produces an acceleration of 1.6g. Rosenbluth and Hicks indicated in a study that the rear acceleration of the head during rope-skipping is 3.5g.[14] As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, activities performed by Ms. Herrera such as playing basketball or lifting weights and typically within the range of normal, daily activities. The energy imparted to the Chevrolet Tracker in which Ms. Herrera was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

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11 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

12 Ng, T.P., Bussone, W.R., Duma, S.M., (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

13 Allen, M. E., I. Weir-Jones, et al. (1994). "Acceleration Perturbations of Daily Living." Spine 19(11): 1285-1290.

14 Rosenbluth, W. and L. Hicks (1994). "Evaluating Low-Speed Rear-End Impact Severity and Resultant Occupant Stress Parameters." Journal of Forensic Science 39: 1393-1424

Ms. Herrera stated that as a result of the subject incident she moved leftward and forward with her left hand hitting the dashboard and her left foot "hit down below." This reported forward motion is contrary to the most basic laws of physics. According to the laws of physics, when contact between the Suzuki and Chevrolet occurred, had there been enough energy transferred to cause any motion; the Chevrolet would have been accelerated and pushed forward. This would have resulted in the vehicle moving forward relative to Ms. Herrera, causing her body to load into the seat and seat back, thus coupling his motion to the vehicle. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[15,16,17]

Findings:

1. On July 16, 2008, Nidia Herrera was the belted driver of a 2002 Chevrolet Tracker that was contacted in the rear at low speed.
2. The change in velocity was below 5 miles per hour with accelerations at or below 2.3g.
3. The acceleration experienced by Ms. Herrera was within the limits of human tolerance, and were comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

The energy imparted to Ms. Herrera was well within the limits of human tolerance and well below the acceleration levels that Ms. Herrera likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Ms. Herrera's reported injuries, or exacerbation of pre-existing injuries, and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA. Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to cause a strain/sprain type injury to any tissue, significant motion, which produces stretching, must occur.

In recent papers by Ng et al.,[20,21] accelerations of the lumbar spine were measured during activities of daily living, and peak accelerations were measured to be an average 5.09g for small females (averaging 1.58 meters in height) and an average 4.24g for mid females (averaging 1.65 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 7g. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender). As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. The accelerations of the head were also measured during activities of daily living, and peak accelerations were measured to be an average 2.79g for sitting quickly in a chair. The measured head accelerations were 8.08g for a vertical leap. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

In a rear impact that produces motion of the vehicle, the Chevrolet Tracker would be pushed forward and Ms. Herrera would have moved rearward relative to the vehicle, until her motion was halted by the seat back. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing what is often referred to as a "whiplash" injury to the neck. This usually occurs when the head hyperextends over the headrest of the seat. In order for a headrest to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The head restraint only needs to reach the base of the skull, as this is the area of the center of rotation of the head, or approximately 4 inches from the top of the skull. The federal standard for seatback height specifies for a minimum height of 700 mm or 27.5 inches. This does not account for seat compression; the seat bottom cushion will compress approximately two to three inches with an occupant of Ms. Herrera's habitus. An anthropometric regression based upon Ms. Herrera's age, maximum reported height, and weight places her seated

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20 Ng, T. P. Bussone, W. R., Duma, S. M., Kress, T. A. (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities." Biomed Sci Instrum, 42:410 415.

21 Ng, T. P. Bussone, W. R., Duma, S. M., Kress, T. A. (2006). "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities." Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

height at approximately 33.9 inches. The seat in the subject Chevrolet Tracker is high enough to have prevented Ms. Herrera's head from extending over the seat in this collision. In addition, Szabo et al.[22], McConnell et al.[23], and West et al.[24] have shown that hyperextension does not occur at energy levels such as were experienced in the subject incident. This is consistent with Ms. Herrera's medical records that indicate she did not contact her head in the subject incident.

The magnitude and direction of the force, due to contact between the vehicles, was insufficient to have produced an injury mechanism for a thoracic or lumbar injury. In the subject incident there would also be no extension of Ms. Herrera's upper torso outside the normal range of motion. There would be less motion in the subject incident than in the simple act of bending over to touch one's toes. There is no causal relationship between Ms. Herrera's claimed back injuries and the subject incident; as there was no injury mechanism present. One would only expect slight extension as the shoulders moved rearward. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. An example of this is when a vertebra is moving in a different direction relative to its neighbor. Only with relative motion is loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic or lumbar spine. A lack of loading to the soft and hard tissues of the thoracic or lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur. Once again, the motion and loading to Ms. Herrera's thoracic and lumbar spine was less than that of the simple act of bending to touch one's toes.

Even if Ms. Herrera could move leftward due to the subject incident, it would not produce an injury mechanism. Several investigators have also considered the human response to lateral impacts. Research by Zaborowski,[25] subjected human volunteers restrained with only a lap belt to lateral impacts. The accelerations utilized during this investigation far exceeded that of the subject incident and no permanent physiological changes were noted with physical complaints limited to minor or moderate transient pain. A follow up study again subjected human volunteers to lateral impacts with acceleration levels that exceeded that associated with the subject incident.[26] No permanent physiological changes were reported and minor complaints were limited to neck muscle

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[22] Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[23] McConnell WE, Howard RP, Guzman HM, Bomar JB, Raddin JH, Benedict JV, Smith HL, and Hatsell CP (1993). *Analysis of Human Test subject Kinematic Responses to Low Velocity Rear End Impacts* (SAE 930889). Warrendale, PA: SAE.

[24] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[25] Zaborowski, A.D. (1964). Human Tolerance to Lateral Impact with Lap Belt Only (SAE 640813). Warrendale, PA. Society of Automotive Engineers.

[26] Zaborowski, A.D. (1964). Lateral Impact Studies: Lap Belt Shoulder Harness Investigations (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

soreness that resolved within a few days. Ewing et al.[27] subjected human volunteers to simulated side impacts with acceleration levels greater than associated with the subject incident. No physical complaints were reported in response to these tests. Further work by Ewing et al.,[28] subjected human volunteers to over one hundred simulated side impacts with acceleration levels greater than associated with the subject incident. Again, no physical complaints were reported in response to these tests. Fugger et al.[29] conducted lateral impact tests involving human volunteers. The acceleration levels again exceeded that associated with the subject incident. Physical complaints immediately after impact were noted following only five of the tests. These complaints were transient in nature and consisted of back pain, and slight headache that lasted only a few minutes. All of the complaints came following the higher energy impacts. Bailey et al.[30] conducted lateral impact tests with human volunteers. Acceleration levels were greater than associated with the subject incident, and no physical symptoms were reported in response to these tests. Restrained human volunteers have also been regularly and repeatedly subjected to acceleration levels greater than that associated with the subject incident without acute lumbar spine trauma.[31,32]

The subject incident lacks the physical mechanism to produce acute trauma to the left foot or hand. Both the magnitude and direction of force was sufficient to produce an injury mechanism for Ms. Herrera in the subject incident. Again, Ms. Herrera would tend to move rearward, if any motion occurred. Therefore, she would unload her foot. This indicates that there was less force on the left foot during the subject incident than prior to the subject incident. Finally, she would not move forward and contact her left hand or arm on the dashboard.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 16, 2008, Nidia Herrera was the belted driver of a 2002 Chevrolet Tracker that was contacted in the rear at low speed.

2. The change in velocity was below 5 miles per hour with accelerations at or below 2.3g.

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27 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

28 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

29 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

30 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA. Society of Automotive Engineers.

31 Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature," National Aeronautics and Space Administrations Memorandum 5-19-59E.

32 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory. NBDL-86R006.

ARCCA

3. The relevant crash severity resulted in accelerations well within the limits of human tolerance, activities performed by Ms. Herrera such as playing basketball or lifting weights and typically within the range of normal, daily activities..

4. There is no causal link between the reported cervical spine injuries, or exacerbation of pre-existing injuries, of Ms. Herrera and this reported collision. Her head and neck was well supported and protected by the seat. Ms. Herrera experiences loading on a daily basis comparable to that experienced in this incident. While minor transient neck pain can certainly occur in a rear-end collision, it is unlikely that it would have required any medical attention and would have resolved itself in a relatively short time. An injury mechanism for the claimed cervical injury was not present in the subject incident.

5. There is no causal link between the reported thoracic or lumbar spine injuries, or exacerbation of pre-existing injuries, of Ms. Herrera and this reported collision. She experiences loading on a daily basis greater than that experienced in this incident.

6. Both the magnitude and direction of force of the subject incident were insufficient to produce an injury mechanism for the claimed left foot or hand injuries of Ms. Herrera.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/clf

EXHIBIT
Probst 4
5-23-17

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November 24, 2009

Dylan E. Jackson, Esquire
Wilson Smith Cochran Dickerson
1700 Financial Center, 1215 Fourth Avenue
Seattle, WA 98161-1007

Re: *Daniel Hazard and Rhonda Roth*
King County Superior Court Cause No.: 08-2-32506-7 SEA
ARCCA File No.: 3808-001

Dear Mr. Jackson:

Thank you for allowing ARCCA, Inc. to participate in the above-referenced case. ARCCA was retained to evaluate the subject incident in relation to Daniel Hazard's claimed injuries. This preliminary analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to revise or supplement this preliminary report if additional information becomes available.

The opinions given in this report are based on my analysis of the photographs of the subject vehicles, Mr. Hazard's medical records and injuries, and other available material, using scientific and engineering methodologies generally accepted in the automotive, accident reconstruction, and occupant crash protection fields.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of occupant crash protection, crash safety, crash survival, and restraint system engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the American Society of Safety Engineers, the American Society of Mechanical Engineers and the Association for the Advancement of Automotive Medicine.

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1 Whitman, G. R., K. A. Brown, et al. (1997). Booster-with-Shield Child Restraint Case Studies (SAE 973307). Second Child Occupant Protection Symposium (A special joint session sponsored by Stapp, AAAM, and IRCOBI). Lake Buena Vista, FL, Society of Automotive Engineers.

2 Moffatt, C. A., E. A. Moffatt, et al. (1984). Diagnosis of Seat Belt Usage in Accidents (SAE 840396). Warrendale, PA, Society of Automotive Engineers.

3 Henderson, M. (1992). In-Depth Study of Crashes Where Child Car Occupants are Injured. Church Point, NSW, Australia, Child Accident Prevention Foundation of Australia.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential. I have also designed, developed, and tested seating and restraint systems. I have performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Background:

According to the State Of Washington Police Traffic Collision Report, on July 14, 2008, Daniel Hazard was the belted driver of a of a 2006 Hummer H2 that was travelling north on Moon Valley Road SE in North Bend, Washington. A 1995 Jeep Wrangler, driven by Alexi Fernandez, was traveling southbound on Moon Valley Road SE. While navigating a bend in the road the incident Jeep entered the lane of travel of the subject Hummer. This resulted in a collinear, or head-on, contact between the two vehicles. The airbags in the subject Hummer did not deploy as a result of the contact between the two vehicles.

Information Reviewed:

- State Of Washington Police Traffic Collision Report, July 14, 2008
- Washington Uniform Court Docket Defendant Copy of Infraction for subject incident
- Medical records of Daniel Hazard
- Thirteen (13) color reproductions of photographs of the subject Hummer H2
- Twenty-five (25) color reproductions of photographs of the incident Jeep Wrangler
- Twenty-seven (27) color reproductions of photographs of the incident site
- Four (4) color reproductions of photographs of the vehicles at the incident scene
- Northwest Auto and Truck Appraisers Estimate of Record for the incident Jeep Wrangler, written by Clark Gemmill, July 24, 2008
- State Farm Insurance Companies Supplement 2 for the subject Hummer H2, appraised by Rafael Alfaro, September 13, 2008
- Snoqualmie Valley Towing Inc. towing receipt for the incident Jeep Wrangler
- Deposition transcript of Daniel Hazard, June 22, 2009
- Deposition transcript of Alexi Fernandez, June 2, 2009
- VINPower and Expert AutoStats data sheets for the subject Hummer H2
- VINPower and Expert AutoStats data sheets for the subject Jeep Wrangler

Injuries:

According to his medical records, Mr. Hazard is claiming the following injury as a result of the subject incident:

- Post-concussive syndrome with closed head injury

Vehicle Damage:

Review of the photographs provided in this case show that the subject Hummer sustained mainly cosmetic damage to the front of the vehicle. The only note of structural damage was that indication that repairs to the front frame length and front frame buckle might be required. However, from the provided photographs there was no significant permanent deformation to the structure of the subject Hummer. The driver's airbag in the subject Hummer did not deploy in the subject incident.

Analysis of Hummer Crash:

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[6,7,8,9,10] Photogrammetry performed on the provided photographs of the incident Hummer H2 revealed the damage due to the subject incident. An engineering analysis[11] indicates that a single 10-mile-per-hour delta-V to the front of a Hummer H2 would induce deformation of greater than 5.5 inches across the entire front of the vehicle. This analysis indicates, then, that the impact in the subject incident is consistent with a front collision resulting in a Delta-V for the Hummer H2 of well below 10 mph (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

The above analysis is consistent with numerous staged low-speed impact tests indicating that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated change in velocity of the subject incident.[12] The above analyses place the change in speed due to contact between the two vehicles well below 10 miles per hour.[13] Utilizing an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms),[14] the peak acceleration associated with a 10-mile-per-hour impact is 4.6g. This acceleration was greater than that experienced by the Hummer H2 in which Mr. Hazard was seated.

Airbags are designed to deploy in the 8 to 14 mile per hour range. As noted previously, the airbags did not deploy in the subject incident. Therefore, the subject incident was below a 14 mile per hour change in velocity for the subject Hummer H2.

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6 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

7 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

9 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

10 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

11 EDCRASH, Engineering Dynamics Corp.

12 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

13 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

14 Anderson, R. A., W. J. B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-End Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

Purpose of Seat Belt Restraints:

The need to restrain occupants within vehicles to provide protection during crashes has been well known for many years in the occupant crash protection area in general, and in the automobile industry in particular. This protection has traditionally been provided through the use of seat belts, which have a threefold purpose:[15]

1) To prevent occupant ejection from the vehicle;
2) To couple the occupant to the vehicle in order to take advantage of the energy management properties provided by the crush of the vehicle's structure, thereby allowing the occupant to "ride down" the forces produced during the crash; and
3) To minimize the "second collision" of the occupant against the interior surfaces of the vehicle.

Expected Kinematics of a Properly Restrained Occupant:

The fundamental laws of physics, as well as the engineering analysis of occupant restraint systems from numerous collisions, crash, and sled tests, and published test results, indicate the kinematic pattern of Mr. Hazard. As the crash forces were applied to the Hummer during the contact with the Jeep, the payout of the shoulder and lap belt webbing would have been limited by the locking of the retractor. The lap and shoulder belts would have distributed the loads between the pelvis and torso of Mr. Hazard's body, reducing the motion of his body and coupling him to the vehicle. Finally, as noted by Mr. Hazard, the lap and shoulder belts prevented any contact with any interior surface of the vehicle.

Discussion:

Based upon review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the performance capabilities of the available restraint system and within the limits of human tolerance. Therefore, a properly restrained driver would not be expected to receive significant injuries.

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

15 NHTSA Standardized Child Passenger Safety Training Program: Instructor Guide, Summer, 2001.

Injuries to the brain and associated soft tissue are the result of direct impact or inertial injury. That is, either head impact or abrupt head movement with associated acceleration, or some combination of the two. Mr. Hazard did not contact his head. Therefore, he would not have any direct contact injuries. The only potential injury mechanism would then be from inertial loading. The accelerations in the subject incident were insufficient to have produced a closed head injury, or, an exacerbation of a prior closed head injury. Cerebral concussion is classically defined as a short-lasting disturbance of neural function typically induced by a sudden acceleration or deceleration of the head, usually without skull fracture.[16] Sudden changes in velocity of the head may result in linear and/or rotational accelerations or decelerations of the brain, thereby causing concussion via shearing strains and stresses in the cortex. However, inertial loading to Mr. Hazard was insufficient to have produced any concussive loading to the head. Mr. Hazard regularly experiences accelerations comparable or greater than that of the automotive collision.

The acceleration experienced due to gravity is 1g, which means that Mr. Hazard's body experiences 1g of loading while in a sedentary state. Any motion or lifting of objects by Mr. Hazard in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[17] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Extensive research has been conducted to investigate the acceleration on the head and neck during various activities of daily living. Research by Larsen et al, has revealed that stepping down a 6, 9, and 13 inch step will result in head accelerations of 1.03g, 1.5g, and 1.7g, respectively.[18] An investigative study by Ng et al has shown that peak head accelerations when jumping off a step are on the average of 3.6g while a vertical leap will produce an average of 5.8g and sitting quickly in a chair will result in an average of 2g.[19] Funk et al subjected 20 volunteers to various activities that loaded the neck. Plopping into a chair produced average peak head accelerations of 3.7g and a head shake produced average peak head accelerations of 3.8g.[20] Additional research has shown that the human body can withstand vertical accelerations of up to 15g without the risk of injury.[21]

16 Shaw, N.A. (2002). The Neurophysiology of concussion. *Progress in Neurobiology* 67: 281-344.

17 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

18 Larson, R.E., et al (2001). "A Comparison of Impact and Vibration Loading on Locomotive Crew Members with Exposures in Activities of Daily Living" Proceedings ASME Rail Transportation Division Ride Quality Conf. RTD-Vol. 20

19 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences* Instrumentation 42: 25-30.

20 Funk, J.R., Cormier, J.M., et al. (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

21 Weiss, M.S. and Lustick, L.S. Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval

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Conclusions:

Based on the foregoing analysis, I conclude with a reasonable degree of engineering and biomedical engineering certainty that:

- Mr. Daniel Hazard was the belted driver of the 2006 Hummer H2 during the subject crash.
- The contact between the two vehicles resulted in a change in velocity of less than 10 miles-per-hour for the subject Hummer H2 and maximum accelerations below 4.6g.
- The magnitude of force and motion experienced by Mr. Hazard's head would be well within the limits of human tolerance. The magnitude and direction of force was insufficient to produce the claimed injuries in the subject incident.

Thank you again for using ARCCA. Please do not hesitate to call if you have any questions or if any new information requiring additional review becomes available.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomedical Engineer

BWP/elf

Biodynamics Laboratory, NBDL-86R006, New Orleans, LA.

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EXHIBIT
PENGAD 800-631-6989
Probst 5
5-22-17 VAY

May 28, 2010

Mary Evenson
Safeco Insurance Co.
PO Box 515097
Los Angeles, CA 90051

Re: *Parkhotyuk, Viktor vs. Joven Legaspi*
ARCCA Case No.: 3271-048
Claim No.: 180348783020

Dear Ms. Evenson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Viktor Parkhotyuk. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, therefore a police incident report for the subject incident is not available. The following incident description is based upon the reviewed documents. On December 23, 2008, Viktor Parkhotyuk was the belted driver of a 2001 Honda Civic that was travelling around the roundabout near the Signature Point Apartments in Kent, Washington. Mr. Joyen Legaspi was the belted driver of a 1996 Toyota T100 traveling around the roundabout near the Signature Point Apartments directly behind the subject Honda Civic. According the available documents, the subject Honda Civic was stopped in the roundabout. Shortly after the subject Honda Civic stopped, the incident Toyota T100 slid on ice, failed to stop in time and the front of the incident Toyota came into contact with the rear of the subject Honda.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Medical records of Viktor Parkhotyuk
- Plaintiff's Demand [11/13/09]
- Summons [1/10/10]
- Ten (10) color digital reproductions of photographs of the subject 2001 Honda Civic
- Eleven (11) color digital reproductions of photographs of the incident 1996 Toyota T100
- Exhibition Automotive Inc. repair estimate for the subject 2001 Honda Civic [1/13/09]
- VinLink data sheet for the subject 2001 Honda Civic
- Expert AutoStats data sheets for a 2001 Honda Civic
- ARCCA inspection of the subject vehicle [5/5/10]

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

1. Identify the injuries that Mr. Parkhotyuk claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Parkhotyuk was occupying;
3. Determine Mr. Parkhotyuk's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Parkhotyuk's response to the subject incident;
5. Evaluate Mr. Parkhotyuk's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the documents, Mr. Parkhotyuk has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Joint dysfunction
  - Myospasms
- Thoracic and Lumbar Spine
  - Sprain/strain
  - Joint dysfunction
  - Myospasms

Damage and Incident Severity:

The severity of the incidents was analyzed by using the photographic reproductions and repair estimates of the subject Honda in association with accepted engineering practices. According to the available documents, the subject incident was a rear impact between the Honda Civic and the Toyota T100, where the primary points of impact to the incident Toyota T100 and the subject Honda Civic were to the front and rear, respectively. The repair estimate for the subject Honda Civic indicated that the primary damage due to the subject incident consisted of cosmetic damage to the rear bumper cover. Review of the photographic reproductions of the subject Honda reveals a group of dents on the right, rear-quarter panel. Note: Upon inspection of the subject vehicle, it was determined that this group of dents was not induced by the subject incident as it is not consistent with direct contact between the rear of the subject Honda and the front of the incident Toyota. Review of the photographic reproductions of the incident Toyota T100 indicated that damage, if any, was cosmetic in nature.

The dent in front of the left rear taillights of the subject Honda is not associated with the subject incident. There were no scratches in the paint or paint transfer markings in the area. The geometry of the dent is more consistent with a pure lateral impact, however it was noted that the subject impact was oblique to longitudinal. The damage to the left rear taillight was not induced from an oblique or rear impact. No components or structures were displaced that would deform the rear quarter panel remote from the point of impact.

Photographic analyses of the provided photographs of the vehicles, my inspection of the subject Honda and repair estimate revealed the damage due to the subject incident. The damage to the subject Honda, as defined by the photographic reproductions, and confirmed by the repair estimate and my inspection, was used to perform a damage threshold speed change analysis.[11] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 2001 Honda Civic. In a five mile-per-hour rear impact the test Honda sustained damage beyond the bumper cover. The only damage to the subject Honda was to the rear bumper cover and left rear taillight assembly. The damage sustained by the Honda in the IIHS rear impact tests is greater than the damage sustained by the subject Honda in the subject incident. This places the subject incident speed at the test speed of less than 5 miles per hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of a nominal 5 miles-per-hour for the subject Honda Civic. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 5 mile-per-hour impact is 2.3g.[12] By the laws of physics, this acceleration was the maximum acceleration experienced by the subject Honda Civic in which Mr. Parkhotyuk was seated.

The acceleration experienced due to gravity is 1g. This means that Mr. Parkhotyuk experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by his in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

jumping are comparable to or greater than the maximum 2.3g associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the Honda in which Mr. Parkhotyuk was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Parkhotyuk was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Parkhotyuk's principle direction of motion would be rearward, relative to his vehicle.

Using the fundamental laws of physics, as well as the engineering analysis of occupant restraint systems from numerous collisions, crash tests, and sled test, the subject Honda Civic's occupant kinematic patterns and possibility of injury can be determined. The laws of physics dictate that when the incident Toyota contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing Mr. Parkhotyuk's seat to move forward relative to his body, which would result in Mr. Parkhotyuk moving rearward relative to the interior of his vehicle. This interaction between Mr. Parkhotyuk and his vehicle's interior would cause his body to load into the seatback structure. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Parkhotyuk would have been limited to well within the range of normal physiological limits.

Findings:

1. On December 23, 2008, Viktor Parkhotyuk was the belted driver of a 2001 Honda Civic that was contacted in the rear at low speed.
2. The change in velocity was a nominal 5 miles per hour with maximum accelerations below 2.3g.

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14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

3. The acceleration experienced by Viktor Parkhotyuk was within the limits of human tolerance and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Viktor Parkhotyuk was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Mr. Parkhotyuk's reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. Joint dysfunction and myospasms secondary injuries to sprain/strain injuries, and are terms used synonymously with sprain/strain injuries to describe pain in the joint complex and muscles while moving within the normal corridors of motion. Of particular interest is whether the subject incident created any of the mechanisms or loads by which the claimed injuries can occur. Evaluation of the injury mechanisms will be addressed for the specific injuries claimed by Mr. Parkhotyuk.

Cervical spine

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the subject Honda Civic would be pushed forward and Mr. Parkhotyuk would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of

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18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2002 Honda Civic, essentially the same as a 2001 Honda Civic, showed that the nominal height of the front driver's seat with an unoccupied, uncompressed seat is 31 inches with the head restraint in the full-down position, and 33 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The head restraint only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Mr. Parkhotyuk's exact height and weight are unknown. However, based upon personal observation, Ms. Parkhotyuk is well below the 95th percentile in height and weight. Based on an anthropometric regression of an 95th percentile male's height (74 inches) and weight (223 pounds) and using Mr. Parkhotyuk's age (18 years), an 18 year old 95th percentile male has a normal seated height of 36.5 inches. Thus, the seat (even in its full-down position) is tall enough to have prevented hyperextension of a person much taller and heavier than Mr. Parkhotyuk and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[20] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[21] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[22] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[23] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Parkhotyuk in the subject incident. The subject incident had an maximum acceleration of a nominal 2.3g. Previous research has shown that cervical spine

20 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

21 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

22 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

23 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[24,25] Mr. Parkhotyuk would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[26,27] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported neck injuries of Mr. Parkhotyuk cannot be made.

Thoracic and Lumbar Injuries

In a rear impact the hips, thoracic and lumbar spines of an occupant are well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic or lumbar spine. Thus, the seatback would limit the range of motion to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spines. The seatback would not allow for hyperextension of Mr. Parkhotyuk's thoracic or lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless the lower portion of the spine is supported with the upper portion unsupported.

Received Time Oct. 13. 2010 10:03AM No. 5988

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As mentioned before, Ng et al. accelerations of the head and spinal structures were measured during activities of daily living. [28,29] Accelerations of the thoracic and lumbar spines were measured during activities of daily living, and peak accelerations were measured to be an average 4.39g for medium males (averaging 1.74 meters in height) and average 3.93g for large

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24 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

25 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

26 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

29 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

males (averaging 1.82 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 5g in medium and large males. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender).

Live human subjects' torsos have regularly been exposed to rear g-levels up to approximately 40g with no acute trauma during rear impacts.[30] The subject incident had an average acceleration below 2.3 g. Mr. Parkhotyuk's thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[31]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The forces created by the incident were well within the limits of human tolerance for thoracic and lumbar strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and the thoracic or lumbar injuries claimed by Mr. Parkhotyuk cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 23, 2008, Viktor Parkhotyuk was the belted driver of a 2001 Honda Civic that was contacted in the rear at low speed.
2. The change in velocity was a nominal 5 miles per hour with maximum accelerations below 2.3g.
3. The acceleration experienced by Viktor Parkhotyuk was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a slightly rearward motion of Mr. Parkhotyuk's body relative to the interior of the vehicle. Any motion would have been well within the normal range of motion and tolerance levels of Mr. Parkhotyuk and the protection afforded by the available restraint system.
5. One would not expect hyperextension of his head and neck due to the minor nature of the subject incident and the height of the seat and head restraint. While minor transient neck pain can certainly occur in a rear-end collision, it is unlikely that it would have required any medical attention and would have resolved itself in a relatively short time. An injury mechanism for the claimed cervical injury was not present in the subject incident.
6. There is no causal link between the reported thoracic or lumbar spine injuries of Mr. Parkhotyuk, or exacerbations of pre-existing injuries, and this reported collision. Mr.

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30 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

31 Gushue, D., Probst, B., et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

ARCCA

Parkhotyuk experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed thoracic or lumbar injuries was not present in the subject incident. There would be not motion of the thoracic or lumbar spine outside of the normal physiologic range of motion.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/elf

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EXHIBIT
Probst 6
5-23-17

July 7, 2010

Donna M. Young, Esquire
Lee Smart P.S., Inc.
1800 One Convention Place
701 Pike Street
Seattle, Washington 98101-3929

Re: *Ripley, Shem*
ARCCA Case No.: 2196-012

Dear Ms. Young:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries of Shem Ripley. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police were not called to the scene of the subject incident, therefore the incident description is based upon the available documents. On July 11, 2008, Mr. Shem Ripley was the belted driver of a 2001 GMC Yukon XL traveling southbound on 100th Avenue NE, near the intersection of NE 132nd Street in Kirkland, Washington. Ms. Barbara Edson was the driver of a 2006 Lexus ES 330 traveling directly behind the subject GMC. According to the available documents, the subject Yukon stopped for a red traffic signal. Shortly after the subject GMC Yukon XL stopped, the front of the incident Lexus contacted the rear of the subject GMC. Note, according to the Vehicle Accident Information form, signed by Shem Ripley, the subject vehicle was a 2002 GMC Yukon; however the VIN for the subject vehicle indentifies the vehicle as a 2001 GMC Yukon XL. According to the available documents, no airbags deployed as a result of the subject incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Vehicle Accident Information form, signed by Shem Ripley [7/16/08]
- Medical records of Shem Ripley *(pre- and post-incident)*
- Forty (40) color digital reproductions of photographs of the subject 2001 GMC Yukon XL
- One (1) color reproduction of a photograph of the subject 2001 GMC Yukon XL
- One (1) color reproduction of a photograph of the incident 2006 Lexus ES 330
- Allstate Insurance Company estimate for the subject 2001 GMC Yukon XL [7/24/08]
- Lexus of Bellevue invoice for the incident 2006 Lexus ES 330 [7/17/08]
- VinLink data sheet for the subject 2001 GMC Yukon XL
- Expert AutoStats data sheets for a 2001 GMC Yukon XL
- VinLink data sheet for the incident 2006 Lexus ES 330
- Expert AutoStats data sheets for a 2006 Lexus ES 330

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

1. Identify the injuries that Mr. Ripley claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Ripley was occupying;
3. Determine Mr. Ripley's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Ripley's response to the subject incident;
5. Evaluate Mr. Ripley's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the documents, Mr. Ripley has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - C6-C7 disc herniation
- Lumbar Spine
  - Sprain/strain
  - Exacerbation of preexisting lumbar spine condition
  - Retroperitoneum cyst-like lesion/mass
- Groin
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject GMC Yukon XL and the incident Lexus ES 330 in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the GMC Yukon XL and the Lexus ES 330, where the primary points of impact to the incident Lexus ES 330 and the subject GMC Yukon XL were to the front and rear, respectively. Based upon the available information, the subject GMC Yukon XL was equipped with a rear trailer receiver/hitch. According to published geometric data and

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[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

measurements of an exemplar GMC Yukon XL, pertaining to the vertical heights of the front and rear bumpers of the Lexus ES 330 and GMC Yukon XL, respectively, during the subject incident the front bumper of the Lexus ES 330 may have contacted the rear trailer receiver/hitch of the GMC Yukon XL. Review of the available photographs of the subject GMC Yukon XL failed to reveal the presence of any significant damage to the rear trailer receiver/hitch. However, there are descriptors on some of the photographs that indicate shifting of the hitch-to-bumper bolts as being present. While it is noted as "shifting", this 360-degree cosmetic damage pattern is more consistent with the removal or installation of the hitch-to-bumper bolts than it is with being a result of the subject incident. According to the repair estimate for the subject GMC Yukon XL, the damage was confined to the rear bumper step pad. (Figure 1) Note, review of the available photographs of the subject GMC Yukon XL reveal unrelated damage to the rear aspect of the vehicle. More specifically, there is a small dent located beneath the left rear taillamp, beneath the left rear quarter panel, as well as a crescent-shaped laceration located on the rear bumper step pad. According to the invoice for the incident Lexus ES 330, the primary damage from the subject incident was to the front bumper and front bumper bracket. In addition, the repair estimate notes unrelated dent damage to the left front fender area of the incident Lexus. Analysis of the photograph of the incident Lexus did not demonstrate any significant structural damage to the front aspect of the vehicle, but rather minor cosmetic deformation to the front license plate and bracket. (Figure 2)

To summarize, there is some unrelated damage present in the reviewed photographs of the subject GMC Yukon XL, such as the dent located beneath the left rear taillamp, the 360-degree cosmetic damage pattern located around the hitch-to-bumper bolts, and the crescent-shaped laceration located on the rear bumper step pad. There is also unrelated damage present in the reviewed photographs of the incident Lexus ES 330, such as dent damage to the left front fender. The aforementioned damage to both of the incident vehicles is not associated with the subject incident. In addition, upon analysis of the available photographs of the subject GMC Yukon XL, the extent of the damage to the rear aspect of the vehicle changes throughout the photographs. For example, the dent located beneath the left rear taillamp is only present in some of the photographs of the subject GMC.

Figure 1. Photographs of the subject 2001 GMC Yukon XL.

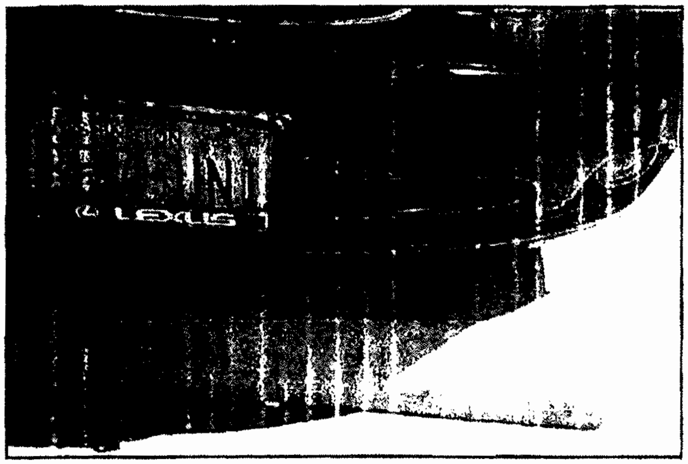

Figure 2. Photograph of the incident 2006 Lexus ES 330.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Using this Law it is possible to analyze the incident Lexus ES 330 to determine the forces on the subject GMC Yukon XL. The forces determined from analysis of the Lexus are, therefore, equal and opposite those of the subject GMC Yukon XL.

For reference, an energy-based crush analysis was performed to evaluate the severity of the subject incident. Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photograph and the itemized invoice of the incident Lexus ES 330 and geometric measurements of a 2006 Lexus ES 330 revealed the crush damage, or lack thereof, due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour impact to the front of a 2006 Lexus ES 330 would result in significant and visibly noticeable crush across the front of the vehicle, with a maximum permanent residual crush of 3.0 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident. The lack of significant structural crush to the 2006 Lexus ES 330 indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour for the Lexus ES 330. (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). This analysis is consistent with an energy-based crush analysis performed on the subject GMC Yukon XL.[17,18,19,20,21,22]

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11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 EDCRASH, Engineering Dynamics Corp.

The damage to the incident Lexus ES 330 from the subject incident, as defined by the photographic reproduction and the itemized invoice was also used to perform a damage threshold speed change analysis.[23] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. In 2002, the IIHS tested a 2002 Lexus ES 300, essentially the same vehicle as the subject 2006 Lexus ES 330, in a series of 5-mile-per-hour impacts. In a 5-mile-per-hour frontal impact into a flat barrier, the IIHS test vehicle's front bumper reinforcement was flattened in its center and required replacement and the right front fender required alignment. The lack of additional damage to the incident Lexus ES 330 is indicative of comparable or less energy transfer or force applied to the incident vehicle compared to the tested vehicle. Therefore, the severity of the IIHS impact is greater than the severity of the subject incident. This places the subject incident speed at or below the test speed of 5 miles-per-hour for the incident Lexus ES 330. Therefore, based upon the fundamental laws of physics and coefficients of restitution, the damage for the subject 2001 GMC Yukon XL is consistent with a collision resulting in a Delta-V comparable to or less than 2.7 miles-per-hour.[24,25,26]

The above analyses are consistent with numerous staged low-speed impact tests that indicate that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[27] Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to or less than 2.7 miles-per-hour for the subject GMC Yukon XL. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 2.7mile-per-hour impact is 1.2g.[28] By the laws of physics, this acceleration was the maximum acceleration experienced by the subject GMC Yukon XL in which Mr. Ripley was seated.

The acceleration experienced due to gravity is 1g. This means that Mr. Ripley experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent

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18 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

19 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

20 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

21 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

22 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

23 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

24 Howard, R.P., Bomar, J. and Bare, C. (1993). Vehicle Restitution Response in Low Velocity Collisions. (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

25 Halliday, D., Resnick, R., Walker, J. (1993). Fundamentals of Physics. New York, John Wiley & Sons.

26 Fricke, Lynn B. (1990). Traffic Accident Reconstruction. Volume 2 of the Traffic Accident Investigation Manual. Evanston, Northwestern University Traffic Institute.

27 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

28 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by him in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[29] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 1.2g associated with the subject incident.[30]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the GMC Yukon XL in which Mr. Ripley was seated was well within the limits of human tolerance. It is also within the personal tolerance levels of Mr. Ripley based upon his activities. According to Mr. Ripley, at the time of the subject incident he owned his own business called Universal Stone Works, which specializes in stone fabrication and installation. He reportedly would regularly lift marble and other stone slabs in excess of 100 pounds with no neck pain. According to the available medical records, after the subject incident Mr. Ripley indicated that he exercised regularly, was able to walk one block and climb a flight of stairs. In addition, it was noted that his stone work was fairly physical and involved a lot of lifting. Furthermore, according to a medical record dated December 8, 2008, approximately five months after the subject incident, Mr. Ripley was noted to still do "a lot of hiking and camping." Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Ripley was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Ripley's principle direction of motion would be rearward, relative to his vehicle.

The laws of physics dictate that when the incident Lexus ES 330 contacted the rear of the subject GMC Yukon XL, had there been enough energy transferred to initiate motion, the GMC Yukon XL would have been pushed forward causing Mr. Ripley's seat to move forward relative to his body, which would result in Mr. Ripley moving rearward relative to the interior of his vehicle. This interaction between Mr. Ripley and his vehicle's interior would cause his body to load into the seatback structure. Specifically, his torso and pelvis would settle back into the seatback. The accelerations resulting from this collision would have caused minimal forward rebound of his

[29] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.
[30] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

body away from the seat back.[31,32,33] However, any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and the seat belt system, then, were such that any motion of Mr. Ripley would have been limited to well within the range of normal physiological limits.

Findings:

1. On July 11, 2008, Shem Ripley was the belted driver of a 2001 GMC Yukon XL that was contacted in the rear at low speed.
2. The change in velocity was at or below 2.7 miles per hour with maximum accelerations below 1.2g.
3. The acceleration experienced by Shem Ripley was within the limits of human tolerance and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Shem Ripley was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Shem Ripley's reported injuries and the subject incident.[34,35]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the

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31 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

32 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

33 Tencer, A. F., S. Mirza, et al. (1995). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

34 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

35 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of bulging, protrusion or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulging, protrusion or herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[36] By definition, a strain occurs when a soft tissue is subjected to significant tension, which overstretches and damages the soft tissue.[37]

Of particular interest is whether the subject incident created any of the mechanisms or loads by which Mr. Ripley's claimed injuries occur. Evaluation of the injury mechanisms will be addressed for the specific injuries claimed by Mr. Ripley.

Cervical Spine

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the GMC Yukon XL would be pushed forward and Mr. Ripley would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2001 GMC Yukon XL, showed that the nominal height of the front driver's seat with an unoccupied, uncompressed seat is 29.25 inches with the head restraint in the full-down position, and 30.75 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The head restraint only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two to three inches under the load of an occupant. Based on an anthropometric regression of Mr. Ripley's age (36 years), height (76 inches) and weight (220 - 250 pounds), Mr. Ripley has a normal seated height of 37.2 - 37.5 inches. According to the Vehicle Accident Information form, signed by Shem Ripley, Mr. Ripley describes the position of his head restraint as being in the midposition. Thus the seat is tall enough to have prevented hyperextension of Mr. Ripley and

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36 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

37 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

one would not expect to see any injuries greater than transient neck stiffness and soreness, due to the minor nature of this incident. In addition, research by Szabo et al.[38] and McConnell et al.[39] has shown that hyperextension does not occur at energy levels such as were experienced in the subject incident. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[40] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[41] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[42] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[43] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Ripley in the subject incident. The subject incident had a maximum acceleration below 1.2g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44,45] Mr. Ripley would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et

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38 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

39 McConnell WE, Howard RP, et al. (1993). Analysis of Human Test subject Kinematic Responses to Low Velocity Rear End Impacts (SAE 930889). Warrendale, PA: Society of Automotive Engineers.

40 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

41 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

42 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

43 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

44 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

45 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

al.,[46,47] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal. daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported neck injuries of Mr. Ripley cannot be made.

Lumbar Spine and Groin

According to the available medical records, Mr. Ripley had a significant positive history of low back pain/disc conditions prior to the subject incident. According to the available documents, Mr. Ripley first developed low back pain in July of 2007 (*approximately 1 year pre-incident*). Shortly after the subject incident, a medical record indicates that Mr. Ripley "has a history of back pain, which has now been aggravated by the car accident." According to an MRI diagnostic report, dated October 27, 2008 (*approximately 3½ months post-incident*), there were findings consistent with a multiloculated cyst-like lesion within the retroperitoneum to the right of midline. Note, there was no evidence of disc herniation, disc space narrowing or spinal stenosis in the lumbar spine. According to a Evergreen Surgical Clinic letter, dated November 11, 2008, it was noted that Mr. Ripley had L4-L5 lower back pain for many years, his MRI scan of this was completely benign, and it was the impression of Dr. Angela D. Zicarelli that Mr. Ripley "has an incidental finding of a mass in the retroperitoneal area in close proximity to the right kidney." Furthermore, Dr. Zicarelli noted that the "CT scan imaging of this does show some renal vascular changes due to size of mass." According to a Summit Rehabilitation, L.L.C. Physical/Occupational Therapy Evaluation and Treatment Plan, dated March 19, 2009, the "tumor behind his kidney" was surgically removed in November of 2008. and was found to be benign. Furthermore, it was noted that Mr. Ripley had a "history of herniated lumbar disc (which) resolved a number of years ago with therapy." Despite the presence of Mr. Ripley's pre-existing low back pain/disc conditions, there is no reason to assume that the claimed exacerbation of prior lumbar spine injuries/conditions is causally related to the subject incident. As previously noted, prior to the subject incident, Mr. Ripley was capable of regularly lifting heavy objects. The lumbar compressive loads associated with lifting and carrying tasks would have been significantly greater than the lumbar compressive forces associated with the subject incident.[48,49]

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46 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

47 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

48 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

49 Kavcic, N., Grenier, S., McGill, S. (2004). "Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises." *Spine* 29(20): 2319-2329.

According to the available documents, at the time of the subject incident, Mr. Ripley's right foot was located on the brake pedal of the subject GMC Yukon XL and his left leg was reportedly extended. In addition, according to a Totem Lake Family Medicine Progress Note, dated July 12, 2008 (*1 day post-incident*) Mr. Ripley's left groin area was noted to be stiff and sore and he was noted as having a groin strain. As previously stated, by definition, a strain occurs when a soft tissue is subjected to significant tension, which overstretches and damages the soft tissue. [50]

There is no reason to assume that the claimed groin strain injury is causally related to the subject incident. The loading and kinematics of his groin region were within the limits of human tolerance and physiological motion. Again, during the subject incident, Mr. Ripley moved rearward relative to his vehicle, away from the floorboard and/or pedals. By so moving, he loaded primarily into the seatback structure. Restraint forces would be applied by the seatback over the large contact area with Mr. Ripley's torso and pelvis. This interaction with the seatback would both limit the motion of his groin region and minimize any forces that might be applied. As previously stated, events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of short duration joint forces of multiple times an individual's body weight.[51]

In a rear impact the hips, thoracic and lumbar spines of an occupant are well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic and lumbar spines and corresponding soft tissues. Thus, the seatback would limit the range of motion to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso and hips, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spines. The seatback would not allow for hyperextension of Mr. Ripley's thoracic or lumbar spines. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless one portion of the spine is supported with another portion unsupported.

As mentioned before, Ng et al. measured accelerations of the head and spinal structures during activities of daily living. [52,53] Accelerations of the thoracic and lumbar spines were measured during activities of daily living, and peak accelerations were measured to be an average 4.39g for medium males (averaging 1.74 meters in height) and average 3.93g for large males (averaging 1.82 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 5g in medium and large males. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender).

Live human subjects' torsos have regularly been exposed to rear g-levels up to approximately 40g with no acute trauma during rear impacts.[54] The subject incident had a maximum

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50 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

51 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

52 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

53 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

54 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

acceleration below 1.2g. Mr. Ripley's thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[55]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The forces created by the incident were well within the limits of human tolerance for lumbar strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and Mr. Ripley's reported lumbar spine injuries, or exacerbations of pre-existing injuries/conditions, cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 11, 2008, Shem Ripley was the belted driver of a 2001 GMC Yukon XL that was contacted in the rear at low speed.
2. The change in velocity was at or below 2.7 miles per hour with maximum accelerations below 1.2g.
3. The acceleration experienced by Shem Ripley was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a slightly rearward motion of Mr. Ripley's body relative to the interior of the vehicle. Any motion would have been well within the normal range of motion and tolerance levels of Mr. Ripley and the protection afforded by the available restraint system.
5. One would not expect hyperextension of Mr. Ripley's head and neck due to the minor nature of the subject incident and the height of the seat and head restraint. While minor transient neck pain can certainly occur in a rear-end collision, it is unlikely that it would have required any medical attention and would have resolved itself in a relatively short time. An injury mechanism for the claimed cervical injury was not present in the subject incident.
6. There is no causal link between the reported lumbar spine injuries of Mr. Ripley, or exacerbations of pre-existing injuries/conditions, and this reported collision. Mr. Ripley experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed lumbar spine injuries was not present in the subject incident. There would be no motion of the lumbar spine outside of the normal physiologic range of motion.
7. Both the magnitude and direction of force were insufficient to produce an injury mechanism in the subject incident to account for Mr. Ripley's claimed groin injury. As such, a causal relationship between the subject incident and the groin injury cannot be made. Therefore, there is no evidence to support the existence of long-term sequelae from the subject incident to Mr. Ripley's groin.

55 Gushue, D., Probst, B., et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

ARCCA

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/elf

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EXHIBIT
Probst 7
5-23-17

July 29, 2010

Bobbie Schultz, SIU Investigator
Liberty Mutual Insurance
16505 SW 72nd Avenue, Bldg F, Suite 200
Portland, OR 97224

Re: *Arthur Vogel*
ARCCA Case No.: 2107-469
Your Claim No.: 14302044-2

Dear Ms. Schultz:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Ahmed Hariri. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

Incident Description:

According to the available documents, on December 14, 2009, Ahmed Hariri was the driver of a Chevrolet Avalanche stopped on the onramp of Interstate 405 near Totem Lake Boulevard NE in Kirkland, Washington. Arthur Vogel was the driver of a 2006 Lincoln Zephyr directly behind the subject Chevrolet. Mr. Vogel stated his foot came off the brake and his vehicle rolled forward. He was unable to stop his vehicle in time and his vehicle contacted the rear of the subject Chevrolet. No airbags in either vehicle deployed and neither vehicle required towing from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Three (3) digital color reproductions of photographs of the subject Chevrolet Avalanche
- Thirteen (13) digital color reproductions of photographs of the incident Lincoln Zephyr
- Audi recording of statement of Arthur Vogel, June 8, 2010
- Transcript of recorded statement of Arthur Vogel, March 23, 2010
- Auto Appraisal Report Liberty Mutual Fire Insurance Company Estimate for the incident Lincoln Zephyr, appraised by Ken Hough, March 25, 2010
- VinPower and Expert AutoStats data sheets for the incident Lincoln Zephyr
- Expert AutoStats data sheets for a Chevrolet Avalanche

Damage and Incident Severity:

The severity of the subject incident was analyzed by using the color digital photographic reproductions of both vehicles and the repair estimate for incident Lincoln. The only noted damage to both vehicles was cosmetic in nature.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Using this Law, it is possible to also analyze the incident Lincoln Zephyr to determine the forces on the subject Chevrolet Avalanche. The forces determined from the analysis of the incident Lincoln Zephyr are, therefore, equal and opposite those of the subject Chevrolet Avalanche. The IIHS tested a 2007 Ford Fusion, essentially the same as a 2006 Lincoln Zephyr. In a five mile-per-hour frontal impact into a flat barrier the test Ford sustained damage to the grille, radiator support and hood. There was only cosmetic damage to the bumper cover of the subject Lincoln. The damage sustained by the Ford in the IIHS frontal impact test is greater than the damage sustained by the incident Lincoln. Thus, this analysis also places the subject incident speed at less than the 5 miles-per-hour of a test speed.

The principle of conservation of momentum was used to determine the change in velocity for the subject Chevrolet, assuming a maximum 5-mile-per-hour Delta-V for the Lincoln Zephyr. The Chevrolet Avalanche has a minimum curb weight of 5400 pounds compared to 3400 pounds for the Lincoln. Therefore, for a maximum 5-mile-per-hour Delta-V for the Lincoln, the Chevrolet would experience approximately a 3.1-mile-per-hour Delta-V.

The above analysis is consistent with numerous staged low-speed impact tests indicating that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[4] Assuming an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms),[5] the acceleration associated with a peak 3.1 mile per hour impact is 1.4 g. Review of the available data, engineering analyses, and my experience indicates an incident resulting in minimal accelerations to the subject Chevrolet Avalanche in which Ahmed Hariri was seated.

The acceleration experienced due to gravity is 1g. This means that Mr. Hariri experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by him in his daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[6] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

In a recent paper by Ng et al.,[7] accelerations of the lumbar spine were measured during activities of daily living, and peak accelerations were measured to be an average 4.39g for medium males (averaging 1.74 meters in height) and average 3.93g for large males (averaging 1.82 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 5g in medium and large males. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender). As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the Chevrolet Avalanche in which Mr. Hariri was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

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4 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

5 Anderson, R. A., W. J. B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-End Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

6 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

7 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

Kinematic Analysis:

According to the laws of physics, when contact between the Chevrolet Avalanche and the Lincoln Zephyr occurred, had there been enough energy transferred to cause any motion; the Chevrolet would have been accelerated and pushed forward. This would have resulted in the vehicle moving forward relative to Mr. Hariri, causing his body to move rearward and to load into the seat and seat back, thus coupling his motion to the vehicle. Szabo et al.,[8] McConnell et al.,[9] and West et al.[10] have shown that hyperextension does not occur at energy levels such as were experienced in the subject incident. In addition, the low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[11,12,13]

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 14, 2009, Ahmed Hariri was the driver of a Chevrolet Avalanche. The subject Chevrolet was contacted in the rear by a Lincoln Zephyr at low speed.
2. The severity of the subject incident is consistent with a Delta-V of a nominal 3.1 miles-per-hour, with a maximum acceleration of 1.4g for the subject Chevrolet Avalanche in which Mr. Hariri was seated.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomedical Engineer

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8 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

9 McConnell WE, Howard RP, Guzman HM, Bomar JB, Raddin JH, Benedict JV, Smith HL, and Hatsell CP (1993). *Analysis of Human Test subject Kinematic Responses to Low Velocity Rear End Impacts* (SAE 930889). Warrendale, PA: SAE.

10 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

11 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

12 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

13 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

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September 24, 2010

Bradley Sands, Esquire
Law Offices of Andersen & Nyburg
650 NE Holladay St
Portland, OR 97232

Re: *Thoens, Susann vs. Safeco Insurance Company of Oregon*
ARCCA Case No.: 2107-477

Dear Mr. Sands:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Susann Thoens. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Thoens-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

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I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, therefore the following incident description is based on other available documents. On July 28, 2007, Susann Thoens was the belted driver of a 2005 Mercedes-Benz E320 traveling west on Northwest Holcomb Boulevard in Portland Oregon. Jessica Thoens was the belted right-front seated passenger in the 2005 Mercedes-Benz E320. Cody Naylen was the driver of a Honda Civic traveling west on Northwest Holcomb Boulevard directly behind the subject Mercedes-Benz E320. According to the available documents, the subject Mercedes-Benz E320 was stopped behind a stopped school bus when the incident Honda failed to stop in time. No airbags were deployed as a result of the impact, and neither vehicle required towing.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Medical records of Susann Thoens
- Fourteen (14) color digital reproductions of photographs of the subject 2005 Mercedes-Benz E320
- Seven (7) color digital reproductions of photographs of the incident Civic
- Recorded Statement Transcript of Susann Thoens [4/15/08]
- Plaintiff's Complaint [11/19/09]
- Safeco Insurance Co. repair estimate for subject 2005 Mercedes-Benz E320 [11/28/07]
- VinLink data sheet for the subject 2005 Mercedes-Benz E320
- Expert AutoStats data sheets for a 2005 Mercedes-Benz E320

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

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1. Identify the injuries that Ms. Thoens claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Thoens was occupying;
3. Determine Ms. Thoens' kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Thoens' response to the subject incident.
5. Evaluate Ms. Thoens' personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the documents, Ms. Thoens has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - C4-5: disc bulge
  - C5-6: disc bulge
  - C6-7: disc bulge
- Thoracic and Lumbar Spines
  - Sprain/strain
- Right Shoulder and Arm
  - Pain
- Inner Ear Concussion Syndrome
- Bilateral Temporomandibular Joints
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject Mercedes-Benz E320 and incident Honda Civic in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the incident Honda and the Mercedes-Benz E320, where the primary points of impact to the incident Honda and the subject Mercedes-Benz E320 were to the front and rear, respectively.

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[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

The rear bumper assembly of a Mercedes-Benz E320 consists of a plastic bumper cover over an aluminum reinforcement bar. The rear bumper covers uses a 5-piece inner plastic stiffener, and the reinforcement bar is bolted to a pair of cylindrical steel brackets and frame sidemember ends. The repair estimate of the subject Mercedes-Benz E320 indicated damage primarily to the rear bumper cover; which was consistent with the reviewed photographic reproductions. The photographic reproductions of the incident Honda revealed primarily cosmetic damage to the front bumper cover.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Mercedes-Benz, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2003 Mercedes-Benz E500, essentially the same vehicle as a 2005 Mercedes-Benz E320. In a five mile-per-hour rear impact into a flat barrier, the test Mercedes-Benz E320 sustained damage to the rear bumper reinforcement/mounting brackets and rear body panel. The primary damage to the subject Mercedes-Benz was to the rear bumper cover. The damage sustained by the Mercedes-Benz in the IIHS rear impact test is greater than the damage sustained by the subject Mercedes-Benz in the subject incident. Therefore, the subject incident is consistent with a rear-collision to the subject Mercedes-Benz resulting in a Delta-V at or below the test speed of 5 miles-per-hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

According to the available documents, Ms. Thoens notes that the incident Honda was traveling 15-20 miles-per-hour upon impact. This speed is an unsupported allegation based on the above analysis, the minor damage revealed in the photographic analysis, and the itemized repair estimates of both vehicles.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V at or below 5 miles-per-hour for the subject Mercedes-Benz E320. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 5 mile-per-hour impact is 2.3g.[12] By the laws of physics, this acceleration was the maximum acceleration experienced by the subject Mercedes-Benz E320 in which Ms. Thoens was seated.

The acceleration experienced due to gravity is 1g. This means that Ms. Thoens experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair,

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Thoens-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Thoens Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

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are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 2.3g associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Mercedes-Benz in which Ms. Thoens was seated was well within the limits of human tolerance. It is also within the personal tolerance levels of Ms. Thoens based upon her self reported activities, such as riding her horses and running 4-5 times per week, which she performed without injury. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Thoens was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Thoens' principle direction of motion would be rearward, relative to her vehicle.

The laws of physics dictate that when the incident vehicle contacted the rear of the subject Mercedes-Benz, had there been enough energy transferred to initiate motion, the Mercedes-Benz would have been pushed forward causing Ms. Thoens' seat to move forward relative to her body, which would result in Ms. Thoens moving rearward relative to the interior of her vehicle. This interaction between Ms. Thoens and her vehicle's interior would cause her body to load into the seatback structure. Specifically, her torso and pelvis would settle back into the seatback. As Ms. Thoens' whole body motion would follow the long axis of the subject vehicle, independent and vertical excursion of her head would not be possible. Finally, the low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Thoens would have been limited to well within the range of normal physiological limits.

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13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

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Findings:

1. On July 28, 2007, Susann Thoens was the belted driver of a 2005 Mercedes-Benz E320 that was contacted in the rear at low speed.
2. The change in velocity was at or below 5 miles-per-hour with maximum accelerations at or below 2.3g.
3. The acceleration experienced by Susann Thoens was within the limits of human tolerance and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Susann Thoens was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Susann Thoens' reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of bulging, protrusion or herniation can result. Based upon

18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.
19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

previous research, the accepted mechanism for acute intervertebral disc bulging, protrusion or herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[20] By definition, a strain occurs when a soft tissue is subjected to significant tension, which overstretches and damages the soft tissue.[21]

Similarly, injuries to the shoulder, arm, ears, temporomandibular joints, and eyes occur when forces are applied in both the manner and magnitude necessary to create the injury mechanism and to exceed the tolerance or strength capacity of the effected tissue. Of particular interest is whether the subject incident created any of the mechanisms or loads by which Ms. Thoens' claimed injuries occur. Evaluation of the injury mechanisms will be addressed for the specific injuries claimed by Ms. Thoens.

Cervical Spine

According to an X-ray pertaining to Ms. Thoens' cervical spine, dated February 4, 2008, there were findings consistent with degenerative disc disease at levels C5-C7. According to a MRI pertaining to Ms. Thoens' cervical spine, dated February 29, 2008, there were findings consistent with disc bulges at C4-C5, C5-C6, and C6-C7. According to an operative report pertaining to Ms. Thoens' cervical spine, dated August 12, 2008, several procedures were performed: discectomies at C3-C4, C4-C5, C5-C6, and C6-C7, fusions at C5-C6 and C6-C7, and disc replacements at C3-C4 and C4-C5.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Mercedes-Benz E320 would be pushed forward and Ms. Thoens would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2003 Mercedes-Benz E320, essentially the same vehicle as a 2005 Mercedes-Benz E320, showed that the nominal height of the front driver's seat with an unoccupied, uncompressed seat is 31.5 inches with the head restraint in the full-down position, and 34.5 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The head restraint only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Thoens' age (54 years), height (63 inches) and weight (159 pounds), Ms. Thoens has a normal seated height of 32.1 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Thoens and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological, one would not expect acute, traumatic injuries to the cervical spine.

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20 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

21 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[22] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[23] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[24] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[25] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Thoens in the subject incident. The subject incident had a peak acceleration of at or below 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[26,27] Ms. Thoens would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[28,29] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

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22 West, D. H., J. P. Gough, et al. (1993). "Thoens Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

23 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

24 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

25 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

26 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

27 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Thoens-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

29 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

According to the reviewed documents, Ms. Thoens was rotated right talking to her daughter in the right-front passenger seat upon impact. Despite her reported rotated position at the time of impact, previous studies have shown that rotation of the head and flexion and/or rotation of the torso would not significantly alter the previously described kinematic analysis, nor would it induce a mechanism for the purported cervical injuries.[30] As described before, a "whiplash" injury occurs when there is relative motion of the head with respect to the torso. In a minor impact, such as the subject incident, the primary mechanism for this injury is for the head to hyperextend over the headrest of the seat. As Ms. Thoens' head did not hyperextend over the headrest, the injury mechanism is not present for her claimed neck injuries.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported neck injuries of Ms. Thoens cannot be made.

Thoracic and Lumbar Spines

According to an X-ray pertaining to Ms. Thoens' thoracic spine, dated February 4, 2008, there were findings consistent with spondylosis in the mid-thoracic spine. According to a MRI pertaining to Ms. Thoens' thoracic spine, dated February 29, 2008, there were findings consistent with facet arthrosis at T9-T10 and T10-T11.

In a rear impact the pelvis, thoracic and lumbar spines of an occupant are well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic or lumbar spines, and pelvis. Thus, the seatback would limit the range of motion to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spines, and pelvis. The seatback would not allow for hyperextension of Ms. Thoens' thoracic or lumbar spines. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless one portion of the spine is supported with another portion unsupported.

As mentioned before, Ng et al. measured accelerations of the head and spinal structures during activities of daily living.[31,32] Accelerations of the thoracic and lumbar spines were measured during activities of daily living, and peak accelerations were measured to be an average 5.09g for small females (averaging 1.58 meters in height) and average 4.24g for medium females (averaging 1.65 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 7g in small and medium females. In the

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30 Kumar, S., Ferrari, R., Narayan, Y. (2005) "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion: Summary of Research" Clinical Biomechanics 20:553-568.

31 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

32 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender).

Live human subjects' torsos have regularly been exposed to rear g-levels up to approximately 40g with no acute trauma during rear impacts.[33] The subject incident had a peak acceleration at or below 2.3 g. Ms. Thoens' thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[34]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The forces created by the incident were well within the limits of human tolerance for thoracic and lumbar strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and the thoracic and lumbar spine injuries claimed by Ms. Thoens cannot be made.

Right Shoulder and Arm

The subject incident lacks the energy and physical mechanism to produce acute trauma to the right shoulder and arm. Both the magnitude and direction of force were insufficient in the subject incident to produce an injury mechanism for Ms. Thoens' claimed right shoulder and arm injury. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. There is no medical evidence of acute macro-traumatic injury to Ms. Thoens' right shoulder and arm in the provided medical records. If the vehicle received any forward motion from the rear impact, Ms. Thoens' response would be rearward relative to the vehicle until her motion was halted by the seat back. Therefore, both the magnitude and direction of force were insufficient in the subject incident to produce a mechanism for the right shoulder or arm sprain/strain type injury.

Injuries to the shoulder occur when an event consists of both the appropriate injury mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The subject incident lacks the presence of the appropriate injury mechanism to produce acute trauma to the rotator cuff of the right shoulder. The rotator cuff is the group of muscles responsible for holding the head of the humerus firmly in the shoulder socket, stabilizing the shoulder joint and allowing for movements of the upper arm. A rotator cuff sprain, or shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons.

By definition, a strain occurs when a soft tissue is subjected to significant tension, which overstretches and damages the soft tissue.[35] The primary mechanisms for a shoulder strain, or shoulder impingement syndrome, are from either indirect loading while the arm is abducted or repetitive microtrauma to the abducted shoulder joint. Acute injury by indirect loading of the shoulder requires that the upper arm be abducted above the shoulder while the force is indirectly

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33 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

34 Gushue, D., Probst, B., et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Thoens-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

35 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

transferred to the shoulder via application to the upper arm. Repetitive microtrauma of the shoulder is a consequence of overuse, especially with regards to overhead activities, and not due to an acute traumatic event. Continual overhead movement of the arms can stress rotator cuff muscles, causing inflammation and eventually tearing.[36,37,38]

The subject incident lacks the energy to produce acute trauma to the right shoulder and arm. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. In her recorded statement, Ms. Thoens' stated that her right shoulder did not come into contact with the interior of the subject vehicle. There is no medical evidence of acute macro-traumatic injury to Ms. Thoens' right shoulder or arm in the subject incident. Thus a causal link between the subject incident and the right shoulder and arm injuries claimed by Ms. Thoens cannot be made.

Inner Ear Concussion Syndrome

Inner ear concussion syndrome, or labyrinthine concussion, is classified by symptoms such as vertigo, hearing loss, tinnitus, and nausea resulting from head trauma. Sudden changes in velocity of the head may result in linear and/or rotational accelerations or decelerations of the brain which can mechanically cause an "inner ear" concussion by damaging the labyrinth bones; alternatively a significant increase in pressure or sound can acoustically damage the labyrinth bones of the ear. The Head Injury Criterion (HIC) has been adopted by the United States federal government as the standard criterion for the determination of risk of a head injury for the Federal Motor Vehicle Safety Standards (FMVSS). In brief, HIC is calculated from resultant accelerations at the center of gravity of the head (based upon three orthogonal directions) that are optimized over a duration of impact.

FMVSS 201, titled Occupant Protection in Interior Impact, specifies requirements to afford impact protection for occupants.[39] More specifically, FMVSS 201 is related to the likelihood of injury resulting from occupant head contact with the interior of a vehicle. FMVSS 201 dictates that when the interior of a vehicle is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, HIC(d), an acronym for Head Injury Criterion (dummy), should not exceed 1000 for any two points in time during the impact which are separated by not more than a 36 millisecond time interval. FMVSS 201 further dictates that when a seatback is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, the deceleration of the headform shall not exceed 80g continuously for more than 3 milliseconds. This requirement is consistent with previous research published by Ono et al. that investigated the human head impact tolerance and the threshold for concussion.[40]

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36 Almekinders, L.C., Banes, A.J., Ballenger, C.A.," *Effects of Repetitive Motion on Human Fibroblasts*," Med Sci Sports Exerc 1993 May 25:603-7

37 O'Neil, B.A., Forsythe, M.E., Stanish, W.D., "*Chronic Occupational Repetitive Strain Injury*," Can Fam Physician 2001 Feb 47:311-6

38 Nakano, K.K., "*Peripheral Nerve Entrapments, Repetitive Strain Disorder, Occupation-Related Syndromes, Bursitis And Tendonitis*," Curr Opin Rheumatol 1991 Apr 3:226-39

39 Federal Motor Vehicle Safety Standard 571.201. Occupant Protection in Interior Impact.

40 Ono, K., Kikuchi, A., et al. (1980). Human Head Tolerance to Sagittal Impact Reliable Estimation Deduced from Experimental Head Injury Using Subhuman Primates and Human Cadaver Skulls. (SAE 801303). Warrendale, PA, Society of Automotive Engineers.

EXHIBIT
Probst 8
5-23-17

ARCCA
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February 2, 2011

Robert Richards, Esq.
Law Offices of Robert A. Richards
11625 Rainier Ave. South
Suite 102
Seattle, WA 98178

Re: *Osborne, Kathrin v. Jennifer Hamilton*
Claim No.: 8130370
ARCCA Case No.: 3989-002

Dear Mr. Richards:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Kathrin Osborne. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on December 22, 2006, Ms. Kathrin Osborne was the restrained driver of a 1993 Nissan Pathfinder traveling northbound on Bendigo Boulevard in North Bend, Washington. Ms. Jennifer Hamilton was the restrained driver of a 2005 Chevrolet Cobalt traveling northbound on Bendigo Boulevard directly behind the Nissan. According to the available documents, the Nissan was stopped in traffic at a red light and the Chevrolet failed to stop in time. As a result, the front bumper of the incident Chevrolet contacted the rear of the subject Nissan. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, No. 2543239
- Twelve (12) grayscale reproductions of the subject vehicle 1993 Nissan Pathfinder
- Ten (10) grayscale reproductions of the subject vehicle 2005 Chevrolet Cobalt
- SCA Appraisal Company West coast appraisal estimate for the subject vehicle 1993 Nissan Pathfinder [December 29, 2006]
- GMAC Insurance Claim Information repair estimate for the incident vehicle 2005 Chevrolet Cobalt [February 28, 2007]
- Deposition Transcript of Kathrin E. Osborne, Kathrin Osborne and Donald Osborne vs. Jennifer Hamilton and John Doe Hamilton [May 14, 2010]
- VinLink data sheet for the subject 1993 Nissan Pathfinder
- Expert AutoStats data sheets for a 1993 Nissan Pathfinder
- VinLink data sheet for the incident 2005 Chevrolet Cobalt
- Expert AutoStats data sheets for a 2005 Chevrolet Cobalt

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

1. Identify the injuries that Ms. Osborne claims was caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Osborne was occupying;
3. Determine Ms. Osborne's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Osborne's response to the subject incident.
5. Evaluate Ms. Osborne's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Osborne has reported the following injuries as a result of the subject incident:

- Lumbar Spine
    - Sprain/strain
    - L4-5 disc bulge

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Nissan Pathfinder and incident Chevrolet Cobalt in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Nissan Pathfinder and the Chevrolet Cobalt, where the primary points of impact to the incident Chevrolet Cobalt and the subject Nissan Pathfinder were to the front and rear, respectively.

The damage estimate of the subject Nissan Pathfinder indicated damage primarily to the rear bumper filler, which is consistent with the reviewed photographic reproductions. The damage estimate of the incident Chevrolet Cobalt indicated damage primarily to the front bumper cover, absorber, impact bar with bracket, left headlamp assembly, hood, and grille, which is consistent with the reviewed photographic reproductions.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the loads sustained by the incident Chevrolet can be

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[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

used to resolve the loads sustained by the subject Nissan. That is, the loads sustained by the incident Chevrolet are equal and opposite to those of the subject Nissan.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the incident Chevrolet Cobalt and geometric measurements of a 2005 Chevrolet Cobalt revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Chevrolet Cobalt would result in significant and visibly noticeable crush across the entirety of the subject vehicle's front structure, with a residual crush of 2.75 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the front of the incident Chevrolet Cobalt indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Utilizing the energy-based crush analysis, review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 7.9 miles-per-hour for the subject Nissan. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the average acceleration associated with a 7.9-mile-per-hour impact is 1.8g.[18], [19] By the laws of physics, the average acceleration experienced by the subject Nissan in which Ms. Osborne was seated was less than 1.8g.

The acceleration experienced due to gravity is 1g. This means that Ms. Osborne experiences 1g of loading while in a sedentary state. Therefore, Ms. Osborne experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Osborne in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short

11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
16 EDCRASH, Engineering Dynamics Corp.
17 Tumbas, NS, Smith, RA, Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
18 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.
19 Tanner, C.B., Wiechel, J.F. Bixel, R.A., Cheng P.H., et al (2001). "Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations" (SAE 2001-01-0891) Warrendale, PA. Society of Automotive Engineers.
20 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that lumbar spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Chevrolet in which Ms. Osborne was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Osborne's claimed injuries in the subject incident.

Kinematic Analysis:

According to Ms. Osborne's testimony, she was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Osborne's principle direction of motion would be rearward, relative to her vehicle.

The laws of physics dictate that when the incident Chevrolet contacted the rear of the subject Nissan, had there been enough energy transferred to initiate motion, the Nissan would have been pushed forward causing Ms. Osborne's seat to move forward relative to her body, which would result in Ms. Osborne moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Osborne and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[22,23,24] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Osborne would have been limited to well within the range of normal physiological limits.

Findings:

1. On December 22, 2006, Ms. Kathrin Osborne was the belted driver of a 1993 Nissan Pathfinder that was contacted in the rear at low speed.
2. The change in velocity was less than 7.9 miles-per-hour with average accelerations well below 1.8g.
3. The acceleration experienced by Ms. Osborne was within the limits of human tolerance, the personal tolerance levels of Ms. Osborne and comparable to that experienced during various daily activities.

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[21] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

[22] Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[23] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[24] Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Osborne was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[27]

Lumbar Spine

According to the available medical records and Ms. Osborne's testimony, there were findings consistent with a L4-5 disc bulge and lumbar sprain/strain .

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[25] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[26] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

[27] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

As previously described, in a rear impact of the type seen here, the lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the lumbar spine. Neither the mechanism, nor the force magnitude; associated with lumbar spine damage, are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine. A lack of loading to the soft and hard tissues of the lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[28] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[29] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[30] The subject incident had an average acceleration significantly below 1.8g. Ms. Osborne's lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[31,32,33,34,35] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[36] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces

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28 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

29 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

30 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

31 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

32 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

33 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

34 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* **16**: 549-559.

35 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

36 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[37]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause or exacerbate prior disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Osborne, a causal link between the subject incident and claimed acute lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 22, 2006, Ms. Kathrin Osborne was the belted driver of a 1993 Nissan Pathfinder that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V well below 7.9 miles-per-hour with an average acceleration well below 1.8g for the subject 1993 Nissan Pathfinder in which Ms. Osborne was seated.
3. The acceleration experienced by Ms. Osborne was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Osborne's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no injury mechanism present in the subject incident to account for Ms. Osborne's claimed lumbar spine injuries. As such, a causal relationship between the subject incident and the lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

[37] Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

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March 9, 2011

Kimberly Cox, Esq.
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Boutelle, Christopher vs. Paul Boucher*
ARCCA Case No.: 2107-476

Dear Mr. Chavez:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident of Christopher Boutelle and Joanna Anderson. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the Pierce County Sheriff Department Incident Report and available documents, on the evening of January 24, 2007, Mr. Paul Boucher was the restrained driver of a 2004 Ford F-250 pickup truck traveling south on Pacific Avenue S in Tacoma, Washington. Mr. Boucher was attempting a left hand turn from Pacific Avenue S onto 131st Street S. According to the available documents, a pedestrian, Ms. Joanna Anderson, crossed north on 131st Street S, and walked into the path of the Ford F-250. As a result, the right front corner of the Ford F-250 contacted Ms. Anderson. Ms. Anderson subsequently died of injuries received.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, January 24, 2007
- Pierce County Sheriff Department Incident Report, January 29, 2007
- Medical records of Joanna Anderson
- Fifteen (15) color photographic reproductions of the subject 2004 Ford F-250
- Twenty (20) color photographic reproductions of the incident scene
- Deposition transcript of Ugene Allen, July 28, 2010
- Deposition transcript of Paul Boucher, July 28, 2010
- ARCCA site inspection, January 25, 2011

Discussion:

It has been questioned as to the timing of the subject incident and how much time Ms. Anderson would have to observe the Boucher vehicle. In addition, the question of available lighting, or visibility, was addressed.

Mr. Boucher testified that he was stopped in the center turn of Pacific Avenue S waiting to turn left onto 131st Street S. He further testified that as he was turning onto 131st Street S he suddenly observed a pedestrian off to the far passenger side of his vehicle. He applied the brakes, contacted the pedestrian, and the vehicle moved a few inches after contact. The police inspection of the subject truck noted a scuff or smudge on the front right bumper below the headlight.

On January 25, 2011, at approximately the same time as the subject incident I observed traffic and recorded the time it takes for a vehicle to leave the center turn lane and travel to the point of contact with Ms. Anderson. The average travel time for a vehicle stopped in the center turn lane was 3.84 seconds. Ms. Anderson was contacted on the extreme right side of the Ford pickup, approximately 1 foot inboard. The average elderly person walks at a pace of approximately 4 feet per second. Therefore, it would have only taken Ms. Anderson approximately 0.25 seconds to

travel one foot. Therefore, she had 3.59 seconds to observe the Ford truck as it was making the turn. This time is the time is takes for a vehicle to travel the distance minus the 0.25 seconds. In this time she would have travelled approximately 14.75 feet. The distance from the curb to the point of contact is approximately 16' 7". This indicates that Ms. Anderson started crossing the road at the same time the vehicle began its turn. Again, it should be noted that the time to complete the turn for a vehicle does not take into account any time for observation of the vehicle as it is stopped, not moving, in the center turn lane. This would add additional time for Ms. Anderson to observe the Ford pickup truck. Based upon this analysis, Ms. Anderson had ample time to observe the Ford truck begin its turn. She also had ample time to stop crossing the street or take other evasive maneuvers to avoid contact with the pickup truck.

Additionally, the illuminance of the area was measured. In the area of the curb the measured value was 1.2 lux. It decreased to 0.7 lux at the area of the fog line and further decreased to 0.2 lux at the point of impact. To place the illuminance in a different context, one footcandle is approximately 10.764 lux. A footcandle is the illuminance cast on a surface by a one-candela source on foot away. A candela can be thought of as the brightness of the flame from a "standard candle" Therefore, the illuminance at the curb was less than one tenth of a candle and decreased towards the point of contact.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. Ms. Anderson had ample time, of approximately 3.59 seconds, to observe the subject Ford F-250 pickup truck begin its turn. She also had ample time to stop crossing the street or take other evasive maneuvers to avoid contact with the pickup truck.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/elf

ARCCA INCORPORATED

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RECEIVED

JUN 20 2011

Kopta and Macpherson

June 17, 2011

Joseph Kopta, Esq.
Kopta & Macpherson
5801 Soundview Drive, Suite 258
Gig Harbor, WA 98335

Re: *Sylvia Leon-Jenkins and Josie Jenkins vs. Debra M. Evans*
Claim No.: 47-4908-925
ARCCA Case No.: 3691-006

Dear Mr. Kopta:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Debra Evans. This letter is meant to supplement my report of May 6, 2011. Since that time, I have had the opportunity to review additional documents. These documents are as follows:

- Deposition transcript of Debra Evans, January 20, 2011
- Deposition transcript of Sylvia Leon-Jenkins, January 19, 2011

Upon review of the additional file material, my opinions regarding the subject incident remain unchanged.

It should be noted in my previous report that it was assumed that contact between the two vehicles did occur. However, this is disputed between the two parties involved. Additionally, there are no objective forensics findings to state, within a reasonable degree of engineering certainty, that contact did occur. In, fact some noted damage is not consistent with the vertical dimensions of both vehicles. Therefore, it is not possible to conclude contact did occur. However, the benefit of doubt was given to Ms. Leon-Jenkins and the event was analyzed as if contact did occur. As noted previously, even if contact did occur, it was insignificant.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

EXHIBIT
PENGAD 800-631-6989
Probst 9
5-23-17

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RECEIVED

MAY 0 9 2011

Kopta and Macpherson

May 6, 2011

Joseph Kopta, Esq.
Kopta & Macpherson
5801 Soundview Drive, Suite 258
Gig Harbor, WA 98335

Re: *Sylvia Leon-Jenkins and Josie Jenkins vs. Debra M. Evans*
Claim No.: 47-4908-925
ARCCA Case No.: 3691-006

Dear Mr. Kopta:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Debra Evans. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the Kitsap County Sheriff's Office Incident/Investigation Report and other available documents, on April 29, 2009, Ms. Sylvia Leon-Jenkins was the restrained driver of a 1998 Saab 900S traveling in the Starbucks drive-thru on Lund Avenue in Port Orchard, Washington. Ms. Debra Evans was the driver of a 2001 Ford Expedition traveling in the drive-thru directly behind the Saab 900S. According to the available documents, the Saab was waiting in line when the car in front pulled forward. Shortly after the front car pulled forward the subject Saab remained stopped and was struck from behind by the incident Ford. As a result, the front bumper of the incident Ford contacted the rear of the subject Saab. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Kitsap County Sheriff's Office Incident/Investigation Report, K09-004985
- Nine (9) color reproductions of the subject vehicle 1998 Saab 900S
- Six (6) grayscale reproductions of the subject vehicle 1998 Saab 900S
- Two (2) color reproductions of the incident vehicle 2001 Ford Expedition
- Trew Auto Body Inc. repair estimate for the subject vehicle 1998 Saab 900S [June 10, 2009]
- FutureForensics Automotive Damage Investigation Report, File #6372 [October 9, 2009]
- Deposition Transcript of Sylvia Leon-Jenkins, *Sylvia Leon-Jenkins and Josie Jenkins vs. Cameron Enterprises, Inc. and/or Cameron Business Enterprises, Inc., ARCO AM/PM Mini-Mart and BP West Coast Products, LLC and Debra M. Evans and John Doe Evans* [January 19, 2011]
- Medical Records pertaining to Sylvia Leon-Jenkins
- VinLink data sheet for the subject 1998 Saab 900S
- Expert AutoStats data sheets for a 1998 Saab 900S
- Expert AutoStats data sheets for a 2001 Ford Expedition

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. Leon-Jenkins claims was caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Leon-Jenkins was occupying;
3. Determine Ms. Leon-Jenkins' kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Leon-Jenkins' response to the subject incident.
5. Evaluate Ms. Leon-Jenkins' personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Leon-Jenkins has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - C5-6 disc protrusion/herniation
- Thoracic and Lumbar Spine
  - Sprain/strain
- Temporomandibular Joint
  - Exacerbation of temporomandibular joint disease
- Left Shoulder
  - Exacerbation of sprain/strain
  - Exacerbation of partial rotator cuff tear
- Left Elbow
  - Exacerbation of sprain/strain
- Left Wrist
  - Exacerbation of sprain/strain
- Left Knee
  - Contusion

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[7] Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Saab 900S and incident Ford Expedition in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Saab and the Ford, where the primary points of impact to the incident Ford and the subject Saab were to the front and rear, respectively.

The damage estimate of the subject Saab indicated damage primarily to the rear bumper cover, which is consistent with the reviewed photographic reproductions. Additionally, a FutureForensics investigation report found that the subject Saab had damage to the rear bumper cover, rear energy absorber and rear reinforcement bar. The photos of the incident Ford indicated no damage to the front of the incident vehicle.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Saab 900S and geometric measurements of a 1998 Saab 900S revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Saab 900S would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 7.0 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Saab 900S indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Saab 900S, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[18] The IIHS tested a 1994 Saab 900S, essentially the same vehicle as a 1998 Saab 900S. In a five mile-per-hour rear impact into a flat barrier the test Saab sustained damage than the subject Saab. The primary damage to the subject Saab was to the rear bumper cover, rear reinforcement bar and rear energy absorber. Thus, because the test Saab in the IIHS rear impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

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11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
16 EDCRASH, Engineering Dynamics Corp.
17 Tumbas, NS, Smith, RA, Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
18 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour for the subject Saab 900S. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[19] By the laws of physics, the average acceleration experienced by the subject Saab in which Ms. Leon-Jenkins was seated was less than 3.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Leon-Jenkins experiences 1g of loading while in a sedentary state. Therefore, Ms. Leon-Jenkins experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Leon-Jenkins in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Saab in which Ms. Leon-Jenkins was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Leon-Jenkins' claimed injuries in the subject incident.

Kinematic Analysis:

According to Ms. Leon-Jenkins testimony and other available documents, Ms. Leon-Jenkins was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Leon-Jenkins' principle direction of motion would be rearward, relative to her vehicle.

Ms. Leon-Jenkins testified that she was looking down at the time of the incident and her body moved forward due to the impact. This is contrary to how the body would move upon impact, the laws of physics dictate that when the incident Ford contacted the rear of the subject Saab, had there been enough energy transferred to initiate motion, the Saab would have been pushed forward causing Ms. Leon-Jenkins' seat to move forward relative to her body, which would result in Ms. Leon-Jenkins moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Leon-Jenkins and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low

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19 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

20 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[22,23,24] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Leon-Jenkins would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 29, 2009, Ms. Sylvia Leon-Jenkins was the belted driver of a 1998 Saab 900S that was contacted in the rear at low speed.
2. The change in velocity was less than 10 miles-per-hour with average accelerations well below 3.0g.
3. The acceleration experienced by Ms. Leon-Jenkins was within the limits of human tolerance, the personal tolerance levels of Ms. Leon-Jenkins and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Leon-Jenkins was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads

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22 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

23 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

24 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

25 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

26 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[27]

Cervical Spine

A cervical spine MRI dated September 8, 2009 of Ms. Leon-Jenkins indicated findings consistent with a minor C5-6 broad based disc protrusion. A C5-6 disc herniation was noted in Ms. Leon-Jenkins other medical documents. Additionally, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Saab would be pushed forward and Ms. Leon-Jenkins would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat. Ms. Leon-Jenkins testified that her headrest was correctly adjusted for her use.

Examination of an exemplar 1995 Saab 900S, essentially the same vehicle as a 1998 Saab 900S, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 29.25 inches in the "full down" position and 31.75 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Leon-Jenkins' age (33 years), height (69 inches) and weight (210 lbs), Ms. Leon-Jenkins has a normal seated height of 34.9 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Leon-Jenkins and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

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[27] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[28] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[29] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[30] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[31] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Leon-Jenkins in the subject incident. The subject incident had an average acceleration of a nominal 3.0g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[32,33] Ms. Leon-Jenkins would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[34,35] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that

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28 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." <u>Accident Reconstruction Journal</u>.

29 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

30 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

31 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

32 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

33 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

34 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", <u>Biomed Sci Instrum</u>. 42:410-415

35 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

exceeded the limits of human tolerance, a causal link between the subject incident and the reported acute cervical spine injuries of Ms. Leon-Jenkins cannot be made.

Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[36] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[37] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[38] The subject incident had an average acceleration significantly below 3.0g. Ms. Leon-Jenkins' thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[39,40,41,42,43] Previous

36 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

37 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

39 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

40 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

41 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[45]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause or exacerbate prior disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Leon-Jenkins, a causal link between the subject incident and claimed acute thoracic and lumbar injuries cannot be made.

Temporomandibular Joint

In general terms, the temporomandibular joint unites the mandible to the cranium. The respective ends of the mandible fit into the articular fossa on either side of the cranium. Inside the joint, a hard fibrocartilaginous disc divides the joint into upper and lower cavities. These cavities contain lubricating fluid referred to as synovial fluid. The disc functions as a space occupying and shock-absorbing structure enabling movements and postures of the condyle.

Temporomandibular injuries are often incorrectly associated with rear-end collisions that cause whiplash injuries and/or flexion-extension motions of the occupant's neck. The theory used to be that the lower jaw motion lagged behind the motion of the head, causing quick and excessive mouth opening/closing during hyperextension of the head. However, scientific studies have shown that the forces in a low-velocity rear-end impacts do not cause any appreciable amount of mouth opening.[46,47] The injury mechanism accepted by the scientific community for acute onset or exacerbation of temporomandibular joint injury is direct contact to the mandible that disrupts joint soft tissue.[48,49] For example an unbelted occupant involved in a frontal impact would likely sustain contact to the mandible through the steering wheel or deployed airbag. As described previously, had the forces associated with the subject incident been great enough to overcome Ms. Leon-Jenkins' muscle

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[42] Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

[43] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[44] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

[45] Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

[46] White, N.A., Yang, K.H. et al. (2005) "Motion Analysis of the Mandible during Low-Speed, Rear-End Impacts using High-Speed X-Rays." Stapp Car Crash Journal 49: 67-84.

[47] McKay, D.C., Christensen, L.V. (1998) "Whiplash Injuries of the Temporomandibular Joint in Motor Vehicle Accidents: Speculations and Facts." Journal of Oral Rehabilitation 25: 731-746.

[48] Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy – Fourth Edition, Lippincott, Williams, & Watkins.

[49] Yun, P., and Kim, Y. (2005). "The Role of Facial Trauma as a Possible Etiologic Factor in Temporomandibular Joint Disorder." Journal of Oral and Maxillofacial Surgeons 63: 1576-1583.

reaction forces, her body would have moved rearward relative to the Chevrolet Malibu's interior. This rearward motion would have been controlled and supported by the seatback and head restraint with little to no forward rebound.[50,51,52] In fact, any forward rebound would have been controlled by the three-point restraint that Ms. Leon-Jenkins was reported to be wearing. During this motion, there would have been no direct contact to her jaw and therefore, no injury mechanism present to cause an acute temporomandibular joint injury. In fact, the forces present during the subject incident were significantly less than those imposed physiologically through actions such as chewing.[53,54] As this crash event did not create the required injury mechanism, and the loads associated with the subject incident did not exceed Ms. Leon-Jenkins' personal tolerance, a causal link between the subject incident and an acute temporomandibular joint injury cannot be established.

Left Upper Extremities

According to the available documents, there were findings consistent with exacerbation of injuries to Ms. Leon-Jenkins upper left extremities due to a prior fall in 2006. This includes exacerbation to the left shoulder, elbow and wrist.

There is no reason to assume that the claimed upper left extremity injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Saab would be pushed forward and Ms. Leon-Jenkins would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. Ms. Leon-Jenkins testified that her hands were not on the steering and she was looking at an object in her lap. This provides no means for Ms. Leon-Jenkins to load her upper extremities. Furthermore, as previously stated Ms. Leon-Jenkins' body would have moved rearward and the interaction with the seatback and her body would have minimized her motion. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Leon-Jenkins' body away from the seatback.[55] Any rebound that may have occurred would have been limited by the available restraint system. Any load acting on the shoulder area due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the injury mechanisms necessary to cause exacerbation or injury to her upper left extremities.

The subject incident had an average acceleration level that was less than 3.0g. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[56]

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50 Saczalski, K., Syson, K., et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

51 Tencer, A.F., Mirza, S., et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

52 Mercedes-Benz of North America, Inc. (1989). "Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209."

53 Lujan-Climent M, Martinez-Gomis J, Palau S, et al. (2008). "Influence of Static and Dynamic Occlusal Characteristics and Muscle Force on Masticatory Performance in Dentate Adults." European Journal of Oral Sciences 116:229-236.

54 Ono T, Kumakura I, Arimoto M, et al. (2007). "Influence of Bite Force and Tongue Pressure on Oro-pharyngeal Residue in the Elderly." Gerodontology 24:143-150.

55 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

56 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

The subject incident lacks the appropriate injury mechanism to produce acute injury or exacerbation to the left upper extremities. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Ms. Leon-Jenkins would tend to move rearward relative to her vehicle. She would not have contacted her upper extremities on any rigid interior object. There was no bruising, laceration, or abrasions associated with interaction of the vehicle interior in the subject incident. For these reasons, a causal link between the subject incident and the left upper extremities injuries claimed by Ms. Leon-Jenkins cannot be made.

Left Knee

Both the magnitude and direction of force in the subject incident were insufficient to produce the injury mechanisms necessary for Ms. Leon-Jenkins's left knee injury. During the subject incident, Ms. Leon-Jenkins would have moved rearward relative to the interior of the subject vehicle. An occupant's body reacts as a whole, thus Ms. Leon-Jenkins's body and lower extremities move rearward relative to her vehicle. In addition, the low accelerations associated with the subject incident would have caused little, or no, forward rebound of her body away from the seat back, thus contact of her lower extremities with the interior of the vehicle would not be expected.[57,58,59] There are no objective medical findings to suggest that Ms. Leon-Jenkins's right lower extremity contacted the interior of her vehicle or that her right lower extremity sustained any chronic, traumatic injury as a result of the subject incident. Therefore a causal link between the subject incident and the reported contusion injuries of Ms. Leon-Jenkins's left lower extremity cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 29, 2009, Ms. Sylvia Leon-Jenkins was the belted driver of a 1998 Saab 900S that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V well below 10 miles-per-hour with an average acceleration well below 3.0g for the subject 1998 Saab 900S in which Ms. Leon-Jenkins was seated.
3. The acceleration experienced by Ms. Leon-Jenkins was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Leon-Jenkins' body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits

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57 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

58 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

59 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

5. There is no injury mechanism present in the subject incident to account for Ms. Leon-Jenkins' claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Leon-Jenkins' claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.
7. The injury mechanism required to cause acute injury or exacerbation to Ms. Leon-Jenkins' temporomandibular joint was not created during the subject incident. As such, causation between the subject incident and claimed injuries of Ms. Leon-Jenkins' temporomandibular joint cannot be established.
8. The injury mechanism required to cause acute injury or exacerbation to Ms. Leon-Jenkins' upper left extremities was not created during the subject incident. As such, causation between the subject incident and claimed injuries of Ms. Leon-Jenkins' upper left extremities cannot be established.
9. Both the magnitude and direction of force were insufficient to produce an acute injury mechanism for the claimed left knee injuries of Ms. Leon-Jenkins in the subject incident.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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LOO 069S - Seattle Legal

June 21, 2011

JUL 05 2011

Lisa Liekhus, Esquire
Law Offices of Kelly J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Claim/Defense # ______________

Retain Original: ____YES ____NO

Re: *Fox, Devonda v. Safeco Insurance Company*
ARCCA Case No.: 2107-540

Dear Ms. Liekhus:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces experienced by Devonda Fox. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available and the claimed injuries of the vehicle occupants, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, American Society of Safety Engineers, the American Society of Mechanical Engineers, and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

EXHIBIT
PENGAD 800-631-6989
Probst 10
5-23-17 MY

Incident Description:

According to the State of Washington Police Traffic Collision Report and reviewed documents, on September 16, 2005, Devonda Fox was the belted driver of a 2000 Dodge Dakota travelling southbound on SR 99 near 168th Street SW in Lynnwood, Washington. Noel Wilder was the driver of a 1996 Toyota Camry behind the subject Dodge Dakota. Ms. Fox observed a Fire Department vehicle and came to a complete stop behind another vehicle. The incident Toyota failed to stop in time. The front of the incident Toyota contacted the rear of the subject Dodge. No airbag in either vehicle deployed; and the vehicles did not require towing from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No.: 2044376
- Thirteen (13) color photographic reproductions of the subject vehicle 2000 Dodge Dakota
- Thirteen (13) color photographic reproductions of the incident vehicle 1996 Toyota Camry
- Dwayne Lane's Everett Dodge repair record for the subject vehicle 2000 Dodge Dakota [October 19, 2005]
- GW Auto Rebuild repair estimate for the subject vehicle 2000 Dodge Dakota [October 14, 2005]
- Claim Summary for the subject vehicle 2000 Dodge Dakota [September 20, 2005]
- Safeco Insurance Company of Illinois repair estimate for the subject vehicle 2000 Dodge Dakota [September 20, 2005]
- Interrogatories and Requests for Production Propounded to Plaintiff's, *Devonda Fox and Robert Fox vs. Noel Wilder and Jane Doe Wilder* [November 10, 2008]
- Deposition Transcript of Devonda Fox, *Devonda Fox vs. Safeco Insurance of Illinois* [May 9, 2011]
- Medical Records pertaining to Devonda Fox
- VinLink data sheet for the subject 2000 Dodge Dakota
- Expert AutoStats data sheets for a 2000 Dodge Dakota
- VinLink data sheet for the incident 1996 Toyota Camry
- Expert AutoStats data sheets for a 1996 Toyota Camry

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[4,5,6,7,8] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Fox claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Fox was occupying;
3. Determine Ms. Fox's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Fox's response to the subject incident.
5. Evaluate Ms. Fox's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the documents, Ms. Fox has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - C4-C5 and C5-C6 mild broad based disc bulge
  - C6-C7 annual tear, broad based disc bulge

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4 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

5 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

6 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

7 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

8 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject Dodge Dakota in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Dodge Dakota and the Toyota Camry, where the primary points of impact to the incident Toyota Camry and the subject Dodge Dakota were to the front and rear, respectively.

The damage estimate of the subject Dodge Dakota indicated damage primarily to the rear bumper and bumper assembly.

Due to a mismatch in bumper heights the Toyota Camry underrode the rear bumper of the Dodge Dakota. Therefore, softer, non-structural elements were contacted.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Dodge, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[9] As mentioned before, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 1998 Dodge Dakota, essentially the same vehicle as a 2000 Dodge Dakota. In a 5-mile-per-hour rear impact into a flat barrier the test Dodge Dakota sustained damage such that the rear of the cab was struck by the bed, denting both the cab and bed. In addition, damage to the bumper and mounting bracket occurred. The primary damage to the subject Dodge was to the rear bumper and assembly. Thus, because the Dodge in the IIHS rear impact test sustained damage beyond the rear bumper and assembly, the severity of the IIHS impact is greater than the severity of the subject incident. This places the subject incident speed at or below the test speed of 5 miles per hour.

It should be noted that Ms. Fox estimated that the incident Toyota Camry was travelling at a speed of 45-50 mph at the time of the subject incident. However, it should also be noted that a 35-mph impact (NHTSA TRC-93-N10) produces significant crush such that the overall length of the vehicle is decreased by 17.75 inches. The front bumper of the subject Toyota was not significantly deformed rearward.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V at or below 5 miles per hour for the subject Dodge Dakota. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 5 mile per hour impact is 2.3g.[10] By the laws of physics, this acceleration was the maximum acceleration experienced by the subject Dodge Dakota in which Ms. Fox was seated.

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9 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

10 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Ms. Fox experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[11] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 1.4g associated with the subject incident.[12]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Dodge in which Ms. Fox was seated was well within the limits of human tolerance. It is also within the personal tolerance levels of Ms. Fox based upon her self reported activities, such as yoga, that she performed without injury. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Fox was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Fox's principle direction of motion would be rearward, relative to her vehicle.

The laws of physics dictate that when the incident Toyota contacted the rear of the subject Dodge, had there been enough energy transferred to initiate motion, the Dodge would have been pushed forward causing Ms. Fox's seat to move forward relative to her body, which would result in Ms. Fox moving rearward relative to the interior of her vehicle. This interaction between Ms. Fox and her vehicle's interior would cause her body to load into the seatback structure. Specifically, her torso and pelvis would settle back into the seatback. According to her deposition testimony, Ms. Fox stated that her neck contacted the head restraint. Thus the rearward motion of Ms. Fox's head and neck were limited by the available head restraint and is consistent with her expected whole-body rearward motion. The low accelerations resulting from this collision would have

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11 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

12 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

caused little, or no, forward rebound of her body away from the seat back.[13,14,15] Any rebound would have been within the range of protection afforded by the available restraint system. According to her deposition testimony, Ms. Fox stated that as a result of the impact she felt the shoulder strap of the seatbelt pull on her shoulder. Thus, Ms. Fox's forward motion was well restrained by the available seatbelt system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Fox would have been limited to well within the range of normal physiological limits.

Findings:

1. On September 16, 2005, Devonda Fox was the belted driver of a 2000 Dodge Dakota that was contacted in the rear at low speed.
2. The change in velocity was at or below 5 miles per hour with maximum accelerations at or below 2.3g.
3. The acceleration experienced by Devonda Fox was within the limits of human tolerance and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Devonda Fox was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Devonda Fox's reported injuries and the subject incident.[16,17]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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13 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

14 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

15 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

16 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

17 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[18]

Cervical spine

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Dodge Dakota would be pushed forward and Ms. Fox would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1999 Dodge Dakota, essentially the same vehicle as a 2000 Dodge Dakota, showed that the nominal height of the front driver's seat with an unoccupied, uncompressed highback seat is 30.5 inches. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The head restraint only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Fox's age (43 years), height (63 inches) and weight (155 pounds), Ms. Fox has a normal seated height of 32.2 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Fox and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[19] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile

18 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

19 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[20] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[21] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[22] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Fox in the subject incident. The subject incident had a peak acceleration of a maximum 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[23,24] Ms. Fox would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[25,26] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

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20 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

21 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

22 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

23 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

24 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

25 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

26 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported neck injuries of Ms. Fox cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On September 16, 2005, Devonda Fox was the belted driver of the subject Dodge Dakota which was contacted in the rear by a Toyota Camry at low speed.
2. The severity of the subject incident is consistent with a Delta-V at or below 5 miles per hour, with a maximum acceleration of 2.3g for the subject Dodge Dakota in which Devonda Fox was seated.
3. The acceleration experienced by Devonda Fox was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a slightly rearward motion of Ms. Fox's body relative to the interior of the vehicle. Any motion would have been well within the normal range of motion and tolerance levels of Ms. Fox and the protection afforded by the available restraint system.
5. One would not expect hyperextension of her head and neck due to the minor nature of the subject incident and the height of the highback seat. While minor transient neck pain can certainly occur in a rear-end collision, it is unlikely that it would have required any medical attention and would have resolved itself in a relatively short time. An injury mechanism for the claimed cervical injury was not present in the subject incident.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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August 1, 2011

Theodore Miller, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *No, Kyoung v. Dukey Boys, Inc.*
Claim No.: 7484 1015 3017
ARCCA Case No.: 2107-547

Dear Mr. Miller:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Kyoung No. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on October 18, 2007, Mr. Kyoung No was the restrained driver of a 2005 Kia Spectra traveling on River Road in Puyallup, Washington. Mr. Robert Evans was the driver of a 2007 Chevrolet Silverado 3500 Flatbed traveling on River Road directly behind the Kia Spectra. According to the available documents, the Kia was stopped for traffic at a stop light and was struck from behind by the incident Chevrolet. As a result, the front bumper of the incident Chevrolet contacted the rear of the subject Kia. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Fifteen (15) color photographic reproductions of the subject 2005 Kia Spectra
- Seventeen (17) color photographic reproductions of the incident vehicle
- Safeco Insurance Company of Illinois repair estimate for the subject 2005 Kia Spectra [November 21, 2007]
- Salatino's Carstar Collision Supplement of Record 1 with Summary for the subject 2005 Kia Spectra [May 8, 2008]
- Salatino's Car/tar Collision Supplement of Record 1 with Summary for the subject 2005 Kia Spectra [May 14, 2008]
- Deposition Transcript of Kyoung No, *Kyoung No and Vivian No vs. Dukey Boys, Inc. and Robert Evans and Jane Doe Evans* [July 13, 2011]
- Medical Records pertaining to Kyoung No
- VinLink data sheet for the subject 2005 Kia Spectra
- Expert AutoStats data sheets for a 2005 Kia Spectra
- VinLink data sheet for the incident 2007 Chevrolet Silverado 3500

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

[7] Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

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1. Identify the injuries that Mr. No claims was caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. No was occupying;
3. Determine Mr. No's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. No's response to the subject incident;
5. Evaluate Mr. No's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. No has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
  - Very tiny disc protrusion posteriorly at the T6-7 level
  - Disc herniation at the L4-5 level
  - Small broad based disc protrusion posteriorly at the L5-S1 level

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Kia Spectra and incident Chevrolet Silverado in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Kia and the Chevrolet, where the primary points of impact to the incident Chevrolet and the subject Kia were to the front and rear, respectively.

The damage estimate of the subject Kia indicated damage primarily to the right quarter panel, lift gate, rear body panel, rear energy absorber, rear bumper cover, and right tail lamp assembly,

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8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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which is consistent with the reviewed photographic reproductions. There was no visible damage to the incident Chevrolet based on the reviewed photographic reproductions.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Kia Spectra and geometric measurements of a 2005 Kia Spectra revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Kia Spectra would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 5.0 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Kia Spectra indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour for the subject Kia Spectra. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mph mile-per-hour impact is 3.0g.[18] By the laws of physics, the average acceleration experienced by the subject Kia in which Mr. No was seated was less than 3g.

The acceleration experienced due to gravity is 1g. This means that Mr. No experiences 1g of loading while in a sedentary state. Therefore, Mr. No experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. No in his daily life would have increased the loading to his body beyond the sedentary 1g. According to the testimony of Mr. No, he participated in martial arts, hiking, billiards, fishing, and camping prior to the subject incident. Additionally he also testified that his job was very physical requiring breaking down of products and stocking shelves. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such

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11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, NS, Smith, RA, Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

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forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Kia in which Mr. No was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. No's claimed injuries in the subject incident.

Kinematic Analysis:

According to his testimony, Mr. No was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. No's principle direction of motion would be rearward, relative to his vehicle. Additionally, Mr. No testified that he was leaning forward with his chin on the steering wheel at the time of the subject incident.

The laws of physics dictate that when the incident Chevrolet contacted the rear of the subject Kia, had there been enough energy transferred to initiate motion, the Kia would have been pushed forward causing Mr. No's seat to move forward relative to his body, which would result in Mr. No moving rearward relative to the interior of the subject vehicle. This interaction between Mr. No and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. No would have been limited to well within the range of normal physiological limits.

Findings:

1. On October 18, 2007, Mr. Kyoung No was the belted driver of a 2005 Kia Spectra that was contacted in the rear at low speed.

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[19] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

[20] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

[21] Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[22] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[23] Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

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2. The change in velocity was less than to 10 miles-per-hour with average accelerations less than 3g.
3. The acceleration experienced by Mr. No was within the limits of human tolerance, the personal tolerance levels of Mr. No and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. No was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and

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[24] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[25] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[26]

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Kia would be pushed forward and Mr. No would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat. According to his testimony, Mr. No's head contacted the headrest.

Examination of an exemplar 2009 Kia Spectra, essentially the same vehicle as a 2005 Kia Spectra, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 32.75 inches in the "full down" position and 35 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. No's age (35 years), height (72 inches) and weight (155 lbs), Mr. No has a normal seated height of 35.2 inches. Thus the seat is tall enough to have prevented hyperextension of Mr. No and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean

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26 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

27 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

28 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

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accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. No in the subject incident. The subject incident had an average acceleration of 3.0g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Mr. No would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Mr. No cannot be made.

Thoracic and Lumbar Spine

According to a thoracic MRI of Mr. No dated December 8, 2007, there were findings consistent with a very tiny disc protrusion posteriorly on the left at the T6-7 level. According to a lumbar MRI of Mr. No dated June 23, 2008, there were findings consistent with a central disc protrusion at the L4-5 level and a mild annular bulge at the L5-S1 level with a high signal annular tear. According to two operative reports of Mr. No's lumbar spine dated November 5, 2008 and October 12, 2009, there were findings consistent with a central L4-5 level herniation and right L4-5 level herniation respectively. Additional available documents indicated there were findings consistent with a thoracic, lumbar, lumbosacral and sacroiliac sprain/strain.

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29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

30 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

31 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

32 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

34 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 3.0g. Mr. No's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the

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[35] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[36] Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[37] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

[38] Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[39] Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[40] Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

[41] Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

[42] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. No, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On October 18, 2007, Mr. Kyoung No was the belted driver of a 2005 Kia Spectra that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour with an average acceleration less than 3.0g for the subject 2005 Kia Spectra in which Mr. No was seated.
3. The acceleration experienced by Mr. No was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. No's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Mr. No's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Mr. No's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

43 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

44 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

ARCCA INCORPORATED

ARCCA, INCORPORATED
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SEATTLE, WA 98105
PHONE 877-942-7222 FAX 206-547-0759
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August 29, 2011

Jason Hoeft, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re:

ARCCA Case No.: 2107-562

Dear Mr. Hoeft:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries in the incident of

ι. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of humau tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

A police incident report was not available for the subject incident. Thus the following incident description is based upon the available documents. On August 16, 2009, was the driver of a 2008 Acura RDX. was the right front seat passenger, was the left rear seat passenger, was the center rear seat passenger and was the right rear seat passenger. The Acura RDX was traveling on Coal Creek Parkway in the far right lane near I-405 in Newcastle, WA. A 2005 Jeep Grand Cherokee also traveling on Coal Creek Parkway in the left lane. The incident Jeep pulled up to the subject Acura and changed lanes, contacting the subject Acura. As a result the right-front of the incident Jeep contacted the left-front of the subject Acura. No airbags were deployed as a result of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Seventeen (17) color photographic reproductions of the subject 2008 Acura RDX
- Twelve (12) grayscale photographic reproductions of the subject 2008 Acura RDX
- Sixteen (16) color photographic reproductions of the incident 2005 Jeep Grand Cherokee
- Stroud's Auto Rebuild repair estimate for the subject vehicle 2008 Acura RDX [August 16, 2009]
- Evergreen Auto Parts preliminary estimate for the subject vehicle 2008 Acura RDX [August 17, 2009]
- Evergreen Auto Parts repair estimate for the subject vehicle 2008 Acura RDX [August 28, 2009]
- Safeco Insurance Company of Illinois repair estimate for the subject vehicle 2008 Acura RDX [August 28, 2009]
- Safeco Insurance Company of Illinois Supplement of Record 1 with Summary for the subject vehicle 2008 Acura RDX [September 23, 2009]
- Precision Autocraft repair estimate for the incident vehicle 2005 Jeep Grand Cherokee [August 21, 2009].
- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff
- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff

ARCCA

- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff
- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff
- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff
- Deposition Transcript of
- Deposition Transcript of
- Deposition Transcript of
- Deposition Transcript of
- Recorded Statement Transcript of
- VinLink data sheet for the subject 2008 Acura RDX
- Expert AutoStats data sheets for a 2008 Acura RDX
- VinLink data sheet for the incident 2005 Jeep Grand Cherokee
- Expert AutoStats data sheets for a 2005 Jeep Grand Cherokee

Injury Summary:

According to the documents, has reported the following injuries as a result of the subject incident:

- Soft tissue injuries to the back

According to the documents, has reported the following injuries as a result of the subject incident:

- Soft tissue injuries to the neck and back

According to the documents, has reported the following injuries as a result of the subject incident:

- Soft tissue injuries to the neck
- Soft tissue injuries to the back left thigh
- Soft tissue injuries to the left shoulder

According to the documents, . has reported the following injuries as a result of the subject incident:

- Soft tissue injuries to the neck and back
- Soft tissue injuries to the left shoulder

Damage and Incident Severity:

The severity of the subject incident was analyzed by using the available documents, testimony, and photographs of the subject Acura and incident Jeep.

An engineering analysis indicates that the damage to the subject Acura is consistent with what can be best described as a sideswipe to the vehicles. This is due to the fact that the incident Jeep was traveling at a shallow angle with respect to the subject Acura just prior to impact. The right-side of the incident Jeep contacted the left-front of the subject Acura. A sideswipe is defined as vehicular contact in which the surface of one vehicle slides against another vehicle or object. In a side swipe, the angle of approach between the two vehicles is shallow and the two contact surfaces do not necessarily achieve a common velocity. Therefore, common approaches for calculating the change in velocity do not readily apply. There was no snagging or engagement in either of the crash events, as is apparent by the limited surface damage to all vehicles involved. A snag may be recognized as a point of deformation that is deformed rearward or forward. The effective normal acceleration of the subject incident is based upon an engineering analysis of the vehicles and residual deformation, and is a nominal 1.0g for each event.[6] This analysis is validated by and consistent with empirical studies.[7]

The damage to the vehicle in the subject incident is consistent with a collision calculated to result in a Delta-V of 2.3 miles-per-hour, assuming an acceleration pulse with the shape of a haversine aud an impact duration of 200 milliseconds (ms). The Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post impact velocity. The above analyses are consistent with numerous staged low-speed impact tests that indicate that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[8] Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in limited change in velocity. By the laws of physics, the calculated acceleration and Delta-V was the maximum experienced by the subject Acura RDX in which the occupants were seated.

The acceleration experienced due to gravity is 1g. This means that the bodies of the occupants of the subject Acura experience 1g of loading while in a sedentary state. Therefore, they experience an essentially equivalent acceleration on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects in their daily lives would have increased the loading to their bodies beyond the sedentary 1g. The joints of the human body are regularly

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6 Toor, A., E. Roentiz, et al. (1999). Practical Analysis Technique for Quantifying Sideswipe Collisions (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

7 Bailey, M. N., B. C. Wong, et al. (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

8 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[9] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. It is also within the personal tolerance levels based upon their self-reported activities that were performed by the various occupants without reported injury. The energy imparted to the Acura RDX was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

During the side swipe event, the occupants of the subject Acura's principle direction of motion would be rearward and slightly leftward, relative to the vehicle.

The laws of physics dictate that when the incident Jeep contacted the subject Acura, the subject Acura would have accelerated longitudinally and accelerated slightly rightward. In this sideswipe event, the occupants would have continued to move at their pre-impact speed and direction. This process would have resulted in a rearward and slightly leftward motion of the occupants' bodies relative to the interior of the subject Acura. The low accelerations in the subject incident were such that any motion of the occupants would have been limited to well within the range of normal physiological limits.

Findings:

1. On August 16, 2009, was the driver of a 2008 Acura RDX. was the right front seat passenger, was the left rear seat passenger, was the center rear seat passenger and was the right rear seat passenger. The left-front was contacted by a 2005 Jeep Grand Cherokee.
2. The contact between the two vehicles is consisteut with side swipe.
3. The change in velocity was 2.3 miles-per-hour with accelerations of a nominal 1g.
4. The acceleration experienced by the occupants of the subject Acura was within the limits of human tolerance and their personal tolerance levels based on an engineering analysis of reported physical activities, and were comparable to that experienced during various daily activities.

[9] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities[10]. The energy imparted to the occupants of the subject Acura was well within the limits of human tolerance, and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link the reported injuries and the subject incident.[11,12]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissne that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching, must occur. A subluxation is a term often used by chiropractic professionals to describe one or more changes that may have occurred in the spine which can not be described by general medical terminology.

Cervical Spine

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a sideswipe event that produces motion of the subject vehicle, the subject Acura would be pushed forward and rightward and the occupants would have moved rearward and leftward relative to the vehicle, until their motion was stopped by the seatback. The only general exposure for injury of a properly seated occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

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10 Gushue, D., Probst, B., et al., (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE

11 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

12 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

However, the minimal accelerations would not allow for hyperextension. With the minimal accelerations and the neck motions withiu a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[13] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[14] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[15] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[16] The above research describes the response of human volunteers subjected to impacts of comparable or greater severity to that experienced by the occupants of the subject Acura in the subject incident. The subject incident had a peak acceleration of a nominal 1g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the acceleratious associated with the subject incident.[17,18]

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[19,20] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

13 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

14 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warreudale, PA: Society of Automotive Engineers.

15 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occnr in low-speed rear impacts?" *European Spine Journal* **6**:366-375.

16 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* **29**:979-987.

17 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Liuear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* **42**: 25-30.

18 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

19 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

20 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size ou Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported acute cervical spine injuries cannot be made.

Thoracic and Lumbar Spine

There is no reason to assume that the claimed thoracic or lumbar spine injuries are causally related to the subject incident. In an impact causing rearward motion; the pelvis, thoracic and lumbar spine of an occupant is well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic and lumbar spine. Thus, the seatback would limit the range of motion to well withiu normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the upper body. The seatback would not allow for hyperextension of the thoracic or lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless one portion of the spine is supported with another portion unsupported. As a result of the subject incident, the occupant's torso and pelvis would settle back into the seatback structures. The low accelerations resulting from this collision would have caused little, or no, forward rebound of the subject Acura occupants' bodies away from the seat backs.[21,22,23] Therefore, significant loading to the thoracic or lumbar spine would not be expected.

As mentioned before, Ng et al. measured accelerations of the head and spinal structures during activities of daily living. [24,25] Accelerations of the lumbar spine were measured during activities of daily living, and peak accelerations were measured to be an average 4.39 g for medium males (averaging 1.74 meters in height) and average 3.93g for large males (averaging 1.82 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 5g in medium and large males. Activities such as performing jumping jacks, leaping vertically and jumping down from a step created peak lumbar accelerations ranging from 4.63g to 21.47g in medium and large males. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender).

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21 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

24 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

25 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

Live human subjects' torsos have regularly been exposed to rear g-levels up to approximately 40g with no acute trauma during rear impacts.[26] The subject incident had peak acceleration less than 1g. The subject Acura's occupants thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of their personal tolerance levels.[27]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic or lumbar spine. The forces created by the incident were well within the limits of humau tolerance for thoracic and lumbar strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and the acute and/or exacerbated thoracic or lumbar spine injuries claimed cannot be made.

By the same analysis, there would not be an injury mechanism for the claimed posterior thigh injury. As noted above the pelvis is restrained by the seat and seatback. Therefore, the posterior this would not have any significant motion either.

Shoulder
The subject incident lacks the energy and physical mechanism to produce acute trauma to the shoulder. Both the magnitude and direction of force were insufficient in the subject incident to produce an injury mechanism for the claimed shoulder injuries. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. If the vehicle received any motion from the impact, the occupant response would be rearward and leftward relative to the vehicle until motion was halted by the seatback. Therefore, both the magnitude and direction of force were insufficient in the subject incident to produce a mechanism for a shoulder sprain/strain type injury.

Injuries to the shoulder occur when an event consists of both the appropriate injury mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The subject incident lacks the presence of the appropriate iujury mechanism to produce acute trauma to the rotator cuff of the right shoulder. The rotator cuff is the group of muscles responsible for holding the head of the humerus firmly in the shoulder socket, stabilizing the shoulder joint and allowing for movements of the upper arm. A rotator cuff sprain, or shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons.

By definition, a strain occurs when a soft tissue is subjected to significant tension, which overstretches and damages the soft tissue.[28] The primary mechanisms for a shoulder strain, or shoulder impingement syndrome, are from either indirect loading while the arm is abducted or repetitive microtrauma to the abducted shoulder joint. Acute injury by indirect loading of the shoulder requires that the upper arm be abducted above the shoulder while the force is indirectly

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26 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

27 Gushue, D., Probst, B., et al. (2006). Effects of Velocity and Occnpant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

28 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

transferred to the shoulder via application to the upper arm. Repetitive microtrauma of the shoulder is a consequence of overuse, especially with regards to overhead activities, and not due to an acute traumatic event. Continual overhead movement of the arms can stress rotator cuff muscles, causing inflammation and eventually tearing.[29,30,31]

The subject incident lacks the energy to produce acute trauma to the shoulder and arm. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Thus a causal link between the subject incident and the shoulder injuries claimed cannot be made

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On August 16, 2009, was the driver of a 2008 Acura RDX. was the right front seat passenger, la was the left rear seat passenger, / was the center rear seat passenger and was the right rear seat passenger. The left-front was contacted by a 2005 Jeep Grand Cherokee.
2. The contact between the two vehicles is consistent with side swipe.
3. The change in velocity was 2.3 miles-per-hour with accelerations of a nominal 1g.
4. The acceleration experienced by the occupants of the subject Acura was within the limits of human tolerance and their personal tolerance levels based on an engineering analysis of their reported physical activities and were comparable to that experienced during various daily activities.
5. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a slightly leftward and rearward motion of the occnpant's bodies relative to the interior of the subject Acura. Any motion would have been well within the normal range of motion and tolerance levels of the occupants.
6. There is no causal link between the reported cervical spine injuries and this reported collision. The occupants of the subject Acura experience loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed cervical injury was not present in the subject incident.
7. There is no causal link between the reported thoracic and lumbar spine injuries and this reported collision. The occupants of the subject Acura's thoracic and lumbar spines experience motion and loading on a daily basis greater than that experienced in this incident.

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29 Almekinders, L.C., Banes, A.J., Ballenger, C.A.," *Effects of Repetitive Motion on Human Fibroblasts*," Med Sci Sports Exerc 1993 May 25:603-7

30 O'Neil, B.A., Forsythe, M.E., Stanish, W.D., "*Chronic Occupational Repetitive Strain Injury*," Can Fam Physician 2001 Feb 47:311-6

31 Nakano, K.K., "*Peripheral Nerve Entrapments, Repetitive Strain Disorder, Occupation-Related Syndromes, Bursitis And Tendonitis*," Curr Opin Rheumatol 1991 Apr 3:226-39

8. There is no causal link between the reported posterior thigh injuries and this reported collision. experienced motion and loading on a daily basis greater than that experienced in this incident.

9. There is no injury mechanism present in the subject incident to account for the claimed shoulder injuries. As the specific injury mechanisms were not created in this collision, a causal relationship between the subject incident and the claimed shonlder injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
PENGAD 800-631-6989
Probst 11
5-23-17 [illegible]

September 21, 2011

Adam C. Cox, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re: *Shim, Jenny v. Joe Swenson*
Claim No.: 378152873008
ARCCA Case No.: 3271-108

Dear Mr. Cox:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Jenny Shim. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

ARCCA

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on May 23, 2008, Ms. Jenny Shim was the unrestrained driver of a 2004 Volvo XC90 parked along the street near 3155 233rd Place SE in Sammamish, Washington. Mr. Joseph Swenson was the driver of a 2005 Ford F150 backing out of his driveway. According to the available documents, as Mr. Swenson maneuvered out of the driveway, the rear of the incident Ford came into contact with the rear of the subject Volvo. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- One hundred thirteen (113) color photographic reproductions of the subject vehicle 2004 Volvo XC90
- Sixty-eight (68) color photographic reproductions of the incident vehicle 2005 Ford F150
- FutureForensics Automotive Damage Investigations Inspection Report [May 14, 2010]
- Declaration of Deputy Sheriff Julie Blessum, *Jenny and John Shim v. Joseph P. and Judith M. Swenson* [July 9, 2009]
- Defendant's First Notice of ER 904 Documents, *Jenny and John Shim v. Joseph P. and Judith M. Swenson* [July 21, 2011]
- Deposition Transcript of Joseph Swenson, *Jenny and John Shim v. Joseph P. and Judith Swenson* [August 13, 2010]
- Deposition Transcript of Jenny Shim, *Jenny and John Shim v. Joseph P. and Judith Swenson* [May 11, 2010]
- Medical Records pertaining to Jenny Shim
- Vehicle Inspection of the subject 2004 Volvo XC90 by Brad Probst [July 27, 2011]
- Vehicle Inspection of the incident 2005 Ford F150 by Brad Probst [July 27, 2011]
- VinLink data sheet for the subject 2004 Volvo XC90
- Expert AutoStats data sheets for a 2004 Volvo XC90
- Expert AutoStats data sheets for a 2003 Volvo XC90
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2003 Volvo XC90
- VinLink data sheet for the incident 2005 Ford F150
- Expert AutoStats data sheets for a 2005 Ford F150

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Shim claims was caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Shim was occupying;
3. Determine Ms. Shim's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Shim's response to the subject incident;
5. Evaluate Ms. Shim's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Shim has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Disc bulge at the C6-7 level
  - Disc herniation at the C6 level
  - Thoracic Outlet Syndrome
- Coccyx injury

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions, available repair estimates, and my vehicle inspections of the subject Volvo XC90 and incident Ford F150 in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Volvo and the Ford, where the primary points of impact to the incident Volvo and the subject Ford were to the rear and rear, respectively.

The FutureForensics inspection of the subject Volvo indicated damage primarily to the left rear side marker lamp, rear bumper cover with parking sensor and rear absorber, which is consistent with the reviewed photographic reproductions and my vehicle inspection. My vehicle inspection of the incident Ford indicated damage consisting on minor scratches on the rear bumper and step pad, which is consistent with the reviewed photographic reproductions.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Volvo XC90, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2003 Volvo XC90, essentially the same vehicle as a 2004 Volvo XC90. In a five mile-per-hour rear impact into a flat barrier the test Volvo sustained damage primarily to the rear bumper cover, rear bumper filler, energy absorber, rear unibody, rear body panel crossmember, and cargo area floorpan. The primary damage to the subject Volvo due to the subject incident was to the left rear side marker lamp, rear bumper cover with parking sensor and rear absorber. Thus, because the test Volvo in the IIHS rear impact test sustained more damage, the severity of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Volvo. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[12] By the laws of physics, the average acceleration experienced by the subject Volvo XC90 in which Ms. Shim was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Shim experiences 1g of loading while in a sedentary state. Therefore, Ms. Shim experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Shim in her daily life would have increased the loading to her body beyond the sedentary 1g. According to her testimony, prior to the subject incident Ms. Shim was capable of performing household chores, cooking, doing laundry, washing dishes, cleaning, and playing with the kids. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Volvo in which Ms. Shim was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Shim's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. Shim was not wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Shim's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. Shim testified that her body went forward and then back due to the impact.

This is contrary to the actual motions, the laws of physics dictate that when the incident Ford contacted the rear of the subject Volvo, had there been enough energy transferred to initiate motion, the Volvo would have been pushed forward causing Ms. Shim's seat to move forward relative to her body, which would result in Ms. Shim moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Shim and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Shim would have been limited to well within the range of normal physiological limits.

Findings:

1. On May 23, 2008, Ms. Jenny Shim was the unbelted driver of a 2004 Volvo XC90 that was contacted in the rear at low speed.
2. The change in velocity was comparable to 5 miles-per-hour with average accelerations significantly below comparable to 1.5g.

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13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

3. The acceleration experienced by Ms. Shim was within the limits of human tolerance, the personal tolerance levels of Ms. Shim and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Shim was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[20]

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18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

20 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

Cervical Spine

According to the available documents, there were findings consistent with a disc bulge at the C6-7 level, a disc herniation at the C6 level and a cervical sprain/strain. Additionally, an MRI review showed findings consistent with mild cervical disc bulges with no significant nerve root impingement.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Volvo XC90 would be pushed forward and Ms. Shim would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2007 Volvo XC90 showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 33.25 inches in height. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Shim's age (37 years), height (62 inches) and weight (120 lbs), Ms. Shim has a normal seated height of 31.7 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Shim and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[21] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[22] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[23] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head

[21] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[22] Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[23] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

restraint, the cervical spine sprain/strain injury threshold is 5g.[24] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Shim in the subject incident. The subject incident had an average acceleration comparable to 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[25,26] Ms. Shim would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[27,28] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Shim cannot be made.

Thoracic Outlet Syndrome

According to the available documents, there were findings consistent with thoracic outlet syndrome.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or

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24 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* **29**:979-987.

25 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" ***Biomedical Sciences Instrumentation*** **42**: 25-30.

26 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[29] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[30] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[31] The subject incident had an average acceleration comparable to 1.5g. Ms. Shim's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[32,33,34,35,36] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[37] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[38]

The neurogenic variety of thoracic outlet syndrome is produced by compression of the components of the brachial plexus, which is a braid of nerves that pass from the neck to the arm. The thoracic outlet is the space between the collarbone and the first rib. The mechanism for thoracic outlet syndrome is an action that results in narrowing of the outlet, such as abducting the arm to 180 degrees (e.g. falling) or a vertically directed force that forces the shoulders down and

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29 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

30 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

31 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

32 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

33 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

34 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

35 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* **16**: 549-559.

36 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

37 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

38 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

back. However, in the subject incident the load path is in a horizontal orientation. Therefore, an injury mechanism for the claimed thoracic outlet syndrome does not exist. Additionally, thoracic outlet syndrome is caused by several activities such as poor posture, repetitive activities with outstretched or over head arm use such as working on computers. [39] Again, in the subject incident Ms. Shim's body would have moved back toward the seatback structures and been well supported.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Shim, a causal link between the subject incident and claimed thoracic outlet syndrome cannot be made.

Coccyx Injury

While there were no specific claims of coccyx injury as a result of the subject incident, there were medical records that indicate a coccyx injury claim might be made. Therefore, for completeness, the potential for coccyx injury was analyzed.

The injury mechanism for a coccyx injury is direct blunt force trauma to the coccygeal region.[40,41] This occurs most often when an individual falls and lands in the sitting position onto their buttocks. Coccyx injury or fracture can also occur during childbirth. When a person is seated, the coccyx acts as a partial weight-bearing structure along with the bilateral ischium. As a seated person leans backwards, more weight is concentrated on the coccyx.

As discussed previously, the compressive spinal forces produced during a rear-end impact are low compared to those experienced during various activities of daily living. These forces are also created due to flexion of the torso, not as the result of a blunt impact to the pelvis or buttocks. [42] An occupant's pelvis and torso will load into the seatback structure during a rear-end impact, effectively dispersing the force on the occupant over the entire pelvic, lumbar, thoracic, and shoulder regions. Therefore, there is no concentrated loading to the coccyx which would produce the mechanism or magnitude of force necessary for a coccyx injury or rupture of an iliolumbar ligament. Extensive rear-end testing with live human subjects has been conducted by numerous researchers. A coccyx injury has never been reported in the hundreds to thousands of documented trials.

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39 Boezaart, A.P., Haller, A., Laduzenski, S., Koyyalanudi, V.B., Ihnatsenka, B., Wright, T., et al. (2010). Neurogenic thoracic outlet syndrome: A case report and review of the literature. *International Journal of Shoulder Surgery* **4(2)**: 27-35.

40 Nahum, A.M. and Melvin, J.W. (2002) Accidental Injury: Biomechanics and Prevention. New York, Springer-Verlag.

41 Moore, K.L., Dalley, A.F., and Agur, A.M.R., (2010). Clinically Oriented Anatomy, Sixth Edition. Philadelphia, Lippincott Williams & Wilkins.

42 Gates, D., Bridges, A., Welch, T., et al., (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On May 23, 2008, Ms. Jenny Shim was the unbelted driver of a 2004 Volvo XC90 that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with an average acceleration comparable to 1.5g for the subject 2004 Volvo XC90 in which Ms. Shim was seated.
3. The acceleration experienced by Ms. Shim was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Shim's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no injury mechanism present in the subject incident to account for Ms. Shim's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Shim's claimed thoracic outlet syndrome. As such, a causal relationship between the subject incident and the thoracic outlet syndrome cannot be made.
7. There is no injury mechanism present in the subject incident to account for Ms. Shim's claimed coccyx injuries. As such, a causal relationship between the subject incident and the coccyx injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
Probst 12
5-23-17

September 23, 2011

Leslie Hasson, Claims Adjuster
Liberty Mutual Insurance Company
P.O. Box 515097
Los Angeles, CA 90051

Re: *Le, Dung v. Bernice Shadbolt*
Claim No.: 4625 6885 4041
ARCCA Case No.: 2107-564

Dear Ms. Hasson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Dung Le. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury. (SAE 940568). Warrendale, PA. Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA. Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA. Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on March 9, 2011, Mr. Dung Le was the restrained driver of a 1998 Toyota Avalon traveling westbound on Pioneer Way East in Tacoma, Washington. Ms. Bernice Shadbolt was the restrained driver of a 2005 Chevrolet Malibu traveling on Pioneer Way East in the lane next to the Toyota. According to the available documents, the Chevrolet turned into the lane on the left causing a collision with the subject Toyota As a result, the left side of the incident Chevrolet contacted the right front of the subject Toyota. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Case No.: 110680323
- Thirteen (13) color photographic reproductions of the subject 1998 Toyota Avalon
- Nine (9) color photographic reproductions of the incident 2005 Chevrolet Malibu
- Safeco Insurance Company of Illinois repair estimate for the subject vehicle 1998 Toyota Avalon [March 10, 2011]
- Safeco Insurance Company of Illinois repair estimate for the incident vehicle 2005 Chevrolet Malibu [March 11, 2011]
- Settlement Demand Letter [August 4, 2011]
- Platinum Investigative Resources, Inc. Surveillance Report of Dung Tan Le [August 24, 2011]
- Medical Records pertaining to Dung Le
- VinLink data sheet for the subject 1998 Toyota Avalon
- Expert AutoStats data sheets for a 1998 Toyota Avalon
- VinLink data sheet for the incident 2005 Chevrolet Malibu
- Expert AutoStats data sheets for a 2005 Chevrolet Malibu

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented

in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Le claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Le was occupying;
3. Determine Mr. Le's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Le's response to the subject incident;
5. Evaluate Mr. Le's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Le has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Right Shoulder
  - Sprain/strain
- Right Knee
  - Complete anterior cruciate ligament (ACL) tear
  - Moderate sprain and partial thickness tear of the posterior cruciate ligament (PCL)
  - Medial and lateral meniscus posterior horn tears

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques. (SAE 831609). Warrendale, PA. Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury. (SAE 940568). Warrendale, PA. Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota Avalon and incident Chevrolet Malibu in association with accepted engineering methodologies. According to the available documents, the subject incident was a right frontal impact between the Toyota Avalon and the Chevrolet Malibu, where the primary points of impact to the incident Chevrolet Malibu and the subject Toyota Avalon were to the left side and right front, respectively.

The damage estimate of the subject Toyota indicated damage primarily to the front bumper cover, right filler, upper support, right mount bracket, grille, right headlamp assembly, hood, right side support, upper tie bar, right fender, and right fender brace, which is consistent with the reviewed photographic reproductions. The damage estimate of the incident Chevrolet indicated damage primarily to the left inner rocker, left rocker molding, left sill plate, left door assembly, back glass, left quarter panel, and required a floor pull, which is consistent with the reviewed photographic reproductions.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Toyota and geometric measurements of a 1998 Toyota Avalon revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the right front of a Toyota Avalon would result in significant and visibly noticeable crush to the subject vehicle's right front structure, with a residual crush of 10.25 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the right front of the subject Toyota Avalon indicates that the subject incident is consistent with a collision resulting in a Delta-V below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of significantly less than 10 miles-per-hour for the subject Toyota. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10-mile-per-hour impact is 3.0g.[18] By the laws of physics, the average acceleration experienced by the subject Toyota in which Mr. Le was seated was significantly less than 3.0g.

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11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA. Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA. Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA. Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740) Warrendale, PA. Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA. Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, NS, Smith, RA. Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View. (SAE 880072). Warrendale, PA. Society of Automotive Engineers.

18 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Mr. Le experiences 1g of loading while in a sedentary state. Therefore, Mr. Le experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Le in his daily life would have increased the loading to his body beyond the sedentary 1g. According to the available documents, prior to the subject incident Mr. Le was capable of exercising, swimming, jogging, performing household chores, gardening and playing soccer with his son. Additionally, the surveillance report of Mr. Le indicated that he was normally walking, carrying groceries and running errands. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average 3g associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota in which Mr. Le was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Le's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Le was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Le's principle direction of motion would be forward and rightward, relative to his vehicle.

The laws of physics dictate that right front contact to the subject Toyota by the left side of the incident Chevrolet would have caused the subject Toyota to decelerate longitudinally and accelerate leftward. Based upon my review of motor vehicle crash tests, results cited in the scientific literature,[21,22] and the laws of physics, had the forces generated during this interaction been sufficient to overcome the muscle reaction forces of Mr. Le, his body would have moved forward and rightward relative to the Toyota's interior. The three-point restraint that Mr. Le was reportedly wearing would have locked when the vehicle accelerations exceeded 0.7g,[23] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Mr. Le, as well as the passive muscle resistance of his arms would have acted in conjunction with his three-point restraint to limit

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19 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

21 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA. Society of Automotive Engineers.

22 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA. Society of Automotive Engineers.

23 Code of Federal Regulations, Federal Motor Vehicle Safety Standard, Title 49, Part 571, Section 209.

body motion. Provided the low accelerations of the subject incident, and the supports described, the bodily response of Mr. Le would have been limited to within normal physiological limits.

Findings:

1. On March 9, 2011, Mr. Dung Le was the belted driver of a 1998 Toyota Avalon that was contacted in the right front at low speed.
2. The change in velocity was significantly less than 10 miles-per-hour with average accelerations significantly less than 3.0g.
3. The acceleration experienced by Mr. Le was within the limits of human tolerance, the personal tolerance levels of Mr. Le and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Le was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

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24 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA. Society of Automotive Engineers.

25 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA. Society of Automotive Engineers.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

As described previously, the vehicle interaction would have caused rearward and leftward acceleration of the subject Toyota. Had the forces generated been sufficient to overcome Mr. Le's muscle reaction forces, his body would have moved forward and rightward relative to the Toyota's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Toyota. Mr. Le's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[26] A kinematic analysis of Mr. Le's response to the subject incident demonstrated that his overall head motion would have been relatively minimal.[27,28] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[29] As a result, Mr. Le's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[30]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[31] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[32] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine injury potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical injury are greater that that associated with the subject incident.[33,34] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[35] None of the

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26 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

27 Araszewski, M., Roenitz, E., and Toor, A., (1999). Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

28 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004). Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

29 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

30 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

31 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

32 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

33 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

34 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

35 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

participants reported any chronic cervical injuries. Arbogast et al.[36] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[37] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

Additionally, researchers such as Zaborowski and Ewing have conducted several investigations that exposed human volunteers to lateral impact accelerations.[38,39,40,41] In response to these tests, physical complaints were transient in nature and none of the participants sustained or reported any cervical spine injuries. Fugger et al.[42] conducted lower severity lateral impacts with human volunteers. Physical complaints following these tests were noted following five tests, but complaints were transient in nature and consisted of back pain or slight headache that lasted a few minutes. Lateral impact research by Bailey et al.[43] again demonstrated that human volunteers sustained comparable severity lateral impacts without the onset of cervical spine injuries. These data are consistent with safe human exposure guidelines to lateral impact accelerations.[44,45]

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[46,47] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

[36] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[37] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory. NBDL-86R006.

[38] Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact with Lap Belt Only (SAE 640843). Warrendale, PA. Society of Automotive Engineers.

[39] Zaborowski, A.B. (1964). Lateral Impact Studies: Lap Belt Shoulder Harness Investigations (SAE 650955) Warrendale, PA. Society of Automotive Engineers.

[40] Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA. Society of Automotive Engineers.

[41] Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA. Society of Automotive Engineers.

[42] Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

[43] Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA. Society of Automotive Engineers.

[44] Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

[45] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory. NBDL-86R006.

[46] Ng, Tp. Bussone, WR, Duma, SM, Kress, TA, (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities". Biomed Sci Instrum. 42:410-415

[47] Ng, Tp. Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities". Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium. (2006) 25-30

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Mr. Le cannot be made.

Lumbar Spine

According to the available medical records, there were findings consistent with a lumbar sprain/strain.

In this type of collision, the motion of Mr. Le's lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Mr. Le's muscle reaction forces, his body would have moved forward and rightward relative to the Toyota's interior. The three-point restraint would have locked during the subject incident and limited his forward body excursion.[48] Therefore, Mr. Le's lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Mr. Le's lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[49] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[50] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[51] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[52] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[53] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic injury. The subject incident had an average acceleration significantly less than 3.0g. Mr. Le's lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.

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48 Code of Federal Regulations. Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

49 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA. Society of Automotive Engineers.

50 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

51 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

52 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA. Society of Automotive Engineers.

53 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory. NBDL-86R006.

Additionally, several investigators have considered the human response to lateral impacts. Research by Zaborowski,[54] subjected human volunteers restrained with only a lap belt to lateral impacts. The accelerations utilized during this investigation exceeded that of the subject incident and no permanent physiological changes were noted with physical complaints limited to minor or moderate transient pain. A follow up study again subjected human volunteers to lateral impacts with acceleration levels that exceeded that associated with the subject incident.[55] No permanent physiological changes were reported and minor complaints were limited to neck muscle soreness that resolved within a few days. Ewing et al.[56] subjected human volunteers to simulated side impacts with acceleration levels greater than associated with the subject incident. No physical complaints were reported in response to these tests. Further work by Ewing et al.,[57] subjected human volunteers to over one hundred simulated side impacts with acceleration levels greater than those associated with the subject incident. Again, no physical complaints were reported in response to these tests. Fugger et al.[58] conducted lateral impact tests involving human volunteers. The acceleration levels again exceeded that associated with the subject incident. Physical complaints immediately after impact were noted following only five of the tests. These complaints were transient in nature and consisted of back pain, and slight headache that lasted only a few minutes. All of the complaints came following the higher energy impacts. Bailey et al.[59] conducted lateral impact tests with human volunteers. Acceleration levels were greater than associated with the subject incident, and no physical symptoms were reported in response to these tests. Restrained human volunteers have also been regularly and repeatedly subjected to acceleration levels greater than that associated with the subject incident without acute lumbar spine trauma.[60,61]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Le, a causal link between the subject incident and claimed lumbar injuries cannot be made.

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54 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact with Lap Belt Only (SAE 640843). Warrendale, PA. Society of Automotive Engineers.

55 Zaborowski, A.B. (1964). Lateral Impact Studies: Lap Belt Shoulder Harness Investigations (SAE 650955). Warrendale, PA. Society of Automotive Engineers.

56 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA. Society of Automotive Engineers.

57 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA. Society of Automotive Engineers.

58 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

59 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA. Society of Automotive Engineers.

60 Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

61 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory. NBDL-86R006.

Right Shoulder Sprain

According to the available documents, there were findings consistent with a right shoulder sprain/strain.

In this type of collision, the motion of Mr. Le's torso would have been well supported and constrained. As previously stated, provided sufficient energy to overcome Mr. Le's muscle reaction forces, his body would have moved forward and rightward relative to the Toyota's interior. The three-point restraint would have locked during the subject incident and limited his forward body excursion.[62] Therefore, Mr. Le's right shoulder would have been moving away from interior structures and toward the open area of the occupant space. Mr. Le's torso motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Mr. Le's right shoulder during the subject incident would have been limited to within normal physiologic limits.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the right shoulder. Finally, the forces created by the incident were well within the limits of human tolerance for the right shoulder and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Le, a causal link between the subject incident and claimed right shoulder injury cannot be made.

Right Knee

According to an MRI diagnostic report pertaining to Mr. Le's right knee, dated April 2, 2011 [*several months post incident*], there were findings indicative of a complete ACL tear, a moderate sprain and partial thickness tear of the PCL, an extensive longitudinal tear of the peripheral posterior horn of the lateral meniscus and a complex tear of the posterior horn of the medial meniscus.

Both the magnitude and direction of forces were insufficient in the subject incident to produce an injury mechanism for Mr. Le's claimed right knee injuries. The loading and kinematics of this area of the body were well within the limits of human tolerance and physiological motion. The medial and lateral menisci are C-shaped fibrocartilaginous structures affixed to the proximal tibial articular surface, whose primary functions are of shock absorbers between the femur and tibia. The typical mechanism for meniscal injury is twisting of the knee when the knee is weight-bearing and flexed.[63] The three-point restraint would have locked during the subject incident and limited his forward and rightward body excursion.[64] These actions do not create the mechanisms required for injury to the ACL, PCL, medial and lateral meniscus. Neither the mechanism nor the force magnitude associated with the claimed knee injures is created by this event.

According to the available documents, at the time of the subject incident Mr. Le was wearing the available seat belt restraint. The forward and rightward motion due to the right frontal impact would have been well controlled by the restraint system. Therefore, there is no mechanism present in the subject incident to account for contact between Mr. Le's right knee and the dash of the Toyota. Furthermore, even if one were to assume that the contact between Mr. Le's right knee and the dash

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[62] Code of Federal Regulations, Federal Motor Vehicle Safety Standard, Title 49, Part 571, Section 209.
[63] Moore K.L. (1985) Clinically Oriented Anatomy, Second Edition, Williams & Wilkins.
[64] Code of Federal Regulations, Federal Motor Vehicle Safety Standard, Title 49, Part 571, Section 209.

occurred, previous research has shown that this force and resulting motion would have been insufficient to cause damage to the posterior horn of the medial and lateral meniscus.[65,66,67,68,69,70,71,72] Additionally, the studies indicate Mr. Le tore his ACL and PCL which requires tibial translation in opposite directions relative to the femur. Varus or valgus rotation of the knee joint would cause significant damage to the collateral ligaments in order to injure the ACL and PCL. As this crash event did not create the required injury mechanism and did not induce force magnitudes that exceeded Mr. Le's personal tolerance limits, a causal link between the subject incident and the claimed right knee injuries cannot be made.[73,74,75,76,77,78]

Finally, Mr. Le was noted to have Ehlers Danlos syndrome. This is a group of inherited disorders that is marked by loose joints, hyperelastic skin which bruises easily, and blood vessels that are easily damaged. This condition would not have allowed for an injury mechanism for the claimed injuries in the subject incident, nor would it produce exacerbation of pre-existing injuries. As noted above, Mr. Le regularly participated in physical activities in which the loading to his body exceeded that of the subject incident.

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65 Balasubramanian, S., Beillas, P., et al. (2004). Below Knee Impact Responses Using Cadaveric Specimens. *Stapp Car Crash Journal* 48: 71-88.

66 Bartsch, A.J., Bolte IV, J.H. et al. (2006). Application of Anthropomorphic Test Device Crash Test Kinetics to Post Mortem Human Subject Lower Extremity Testing (SAE 2006-01-0251). Warrendale, PA, Society of Automotive Engineers.

67 Meyer, E.G. and Haut, R.C. (2003). The Effect of Impact Angle of Knee Tolerance to Rigid Impacts. *Stapp Car Crash Journal* 47: 1-19.

68 Ewers, B.J., Jayaraman, V.M. et al. (2000). The Effect of Loading Rate on the Degree of Acute Injury and Chronic Conditions in the Knee After Blunt Impact (SAE 2000-01-SC20). Warrendale, PA, Society of Automotive Engineers.

69 Stevens, K.J., and Dragoo, J.L. (2006). Anterior Cruciate Ligament Tears and Associated Injuries. *Top Magn Reson Imaging* 17(5): 347-362.

70 Moore K.L. (1985) Clinically Oriented Anatomy, Second Edition, Williams & Wilkins.

71 Kajzer, J., Schroeder, G. et al. (1997). Shearing and Bending Effects at the Knee Joint at High Speed Lateral Loading (SAE 973326). Warrendale, PA, Society of Automotive Engineers.

72 Jayaraman, V.M., Sevensma, E.T. et al. (2001). Effects of Anterior-Posterior Constraint on Injury Patterns in the Human Knee During Tibial-Femoral Joint Loading from Axial Forces through the Tibia (SAE 2001-22-0021). Warrendale, PA, Society of Automotive Engineers.

73 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

74 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger. Philadelphia, London.

75 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

76 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

77 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

78 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On March 9, 2011, Mr. Dung Le was the belted driver of a 1998 Toyota Avalon that was contacted in the right front at low speed.
2. The severity of the subject incident was consistent with a Delta-V significantly less than 10 miles-per-hour with an average acceleration significantly less than 3.0g for the subject 1998 Toyota Avalon in which Mr. Le was seated.
3. The acceleration experienced by Mr. Le was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Le's body forward and rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits
5. There is no causal link between the reported cervical spine injuries of the occupant and this reported collision. Mr. Le experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed cervical injury was not present in the subject incident.
6. There is no causal link between the reported lumbar injuries of the occupant and this reported collision. Mr. Le experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed lumbar injury was not present in the subject incident.
7. There is no causal link between the reported right shoulder injury of the occupant and this reported collision. Mr. Le experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed right shoulder injury was not present in the subject incident.
8. There is no causal link between the reported right knee injuries of the occupant and this reported collision. Mr. Le experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed right knee injuries was not present in the subject incident.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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PENGAD 800-631-6989
Probst 13
5-22-17 L.P.

October 6, 2011

Mary Evenson
Safeco Insurance Company
P.O. Box 515097
Los Angeles, CA 90051

Re: *Miller, Sylvia v. Donald McCulloch*
Claim No.: 159297044018
ARCCA Case No.: 3271-115

Dear Ms. Evenson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Sylvia Miller. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of both the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury. (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques. (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On August 17, 2010, Ms. Sylvia Miller was the restrained driver of a 1991 Honda Civic traveling through a parking lot in Yelm, Washington. Mr. Donald McCulloch was the driver of a 2002 Acura MDX traveling across the parking lot perpendicular to the Honda. According to the available documents, the incident Acura entered the lane in which the Honda was traveling causing contact between the vehicles. As a result, the front of the incident Acura came into contact with the right rear side of the subject Honda. No airbags were deployed as a result of the subject incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eleven (11) color photographic reproductions of the subject 1991 Honda Civic
- First National Insurance Company of America repair estimate for the subject vehicle 1991 Honda Civic [August 25, 2010]
- First National Insurance Company of America unrelated prior damage for the subject vehicle 1991 Honda Civic [August 25, 2010]
- Claim Summary for the subject vehicle 1991 Honda Civic [August 25, 2010]
- First National Insurance Company of America repair estimate for the incident vehicle 2002 Acura MDX [September 1, 2010]
- Medical Records pertaining to Sylvia Miller
- VinLink data sheet for the subject 1991 Honda Civic
- Expert AutoStats data sheets for a 1991 Honda Civic
- VinLink data sheet for the incident 2002 Acura MDX
- Expert AutoStats data sheets for a 2002 Acura MDX
- Expert AutoStats data sheets for a 2001 Acura MDX
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2001 Acura MDX

Injury Summary:

According to the documents, Ms. Miller has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic and Lumbar Spine
    - Sprain/strain

Damage and Incident Severity:

The severity of the subject incident was analyzed by using the available documents, repair estimates and photographs of the subject Honda and incident Acura. The repair estimate for the subject Honda indicated damage primarily to the right rear door shell, right quarter panel, right wheel opening, and a floor pull; which was consistent with the reviewed photographic reproductions. The repair estimate for the incident Acura indicated damage to the center filler, front bumper cover, and license plate bracket.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Acura can be used to resolve the loads sustained by the subject Honda. That is, the forces sustained by the incident Acura are equal and opposite to those of the subject Honda.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Acura, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[6] The IIHS tested a 2001 Acura MDX, essentially the same vehicle as a 2002 Acura MDX. In a five mile-per-hour frontal impact into a flat barrier the test Acura sustained damage beyond the bumper cover and center filler. Damage was noted to the front bumper reinforcement bar. The primary damage to the incident Acura was to the center filler, front bumper cover, and license plate bracket. Thus, because the test Acura in the IIHS frontal impact test sustained comparable damage, if not greater damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour. This is also consistent with an energy based crush analysis. [7,8,9,10,11]

Utilizing the analysis described above, the principles of engineering, and the conservation of momentum,[12,13,14] the subject incident would have caused a lateral Delta-V impact to the Honda that was comparable to 9.4 mph.[15] Using an acceleration pulse with the shape of a haversine and a pulse width of 150 milliseconds, the average acceleration associated with a 9.4 mph Delta-V is

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6 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

7 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

9 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

10 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

11 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

13 Vehicle Research and Test Center, 1997 Thomas Built Bus into a Flat Frontal Barrier. TRC Test Number 990421-1, April – June 1999.

14 Transportation Research Center, Heavy Truck into Left Side of 1995 Blue Bird Bus. TRC Test Number 990525, May - July 1999.

15 Howard, R.P., Bomar, J., et al. (1993). Vehicle Restitution Response in Low Velocity Collisions (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

2.9g.[16,17,18] As a result, the Honda in which Ms. Miller was seated during the lateral impact event, was exposed to a Delta-V less than 9.4 mph with an effective acceleration level less than 2.9g.

The acceleration experienced due to gravity is 1g. This means that the body of Ms. Miller experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the Honda in which Ms. Miller was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Miller was wearing the available three-point restraint system at the time of the subject incident. During the lateral impact event, Ms. Miller's principle direction of motion would be rightward and slightly forward, relative to the subject vehicle.

The laws of physics dictate that when the incident Acura contacted the subject Honda, the subject Honda would have accelerated leftward and decelerated slightly. In this lateral impact event, Ms. Miller would have continued to move at her pre-impact speed and direction. This process would have resulted in a rightward and slight forward motion of Ms. Miller's body relative to the interior of the subject Honda. The lap and shoulder belt would have restrained Ms. Miller's pelvis and torso and would have coupled her motion to the subject Honda. The low accelerations in the subject incident and the restraint provided by the seatbelt system, then, were such that any motion of Ms. Miller would have been limited to well within the range of normal physiological limits.

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16 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

17 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts (SAE 970120). Warrendale, PA. Society of Automotive Engineers.

18 Heinrichs, B.E., Lawrence, J.M., Allin, B.D., et al. (2001). Low-Speed Impact Testing of Pickup Truck Bumpers (SAE 2001-01-0893). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

Findings:

1. On August 17, 2010, Ms. Sylvia Miller was the belted driver of a 1991 Honda Civic when the right rear side was contacted by a 2002 Acura MDX.
2. The contact between the two vehicles is consistent with a lateral impact for the Honda.
3. The change in velocity was less than 9.4 miles-per-hour with accelerations less than 2.9g.
4. The acceleration experienced by Ms. Miller was within the limits of human tolerance and the personal tolerance levels of Ms. Miller based on an engineering analysis of Ms. Miller's physical activities and was comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities.[20] The energy imparted to Ms. Miller was well within the limits of human tolerance, and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Ms. Miller's reported injuries and the subject incident.[21,22]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, in order for a strain/sprain type injury to occur to any tissue, significant motion, which produces stretching, is required. Of particular interest is whether the subject incident created any of the mechanisms or loads by

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20 Gushue, D., Probst, B., et al., (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE

21 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

22 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

which Ms. Miller's claimed injuries occur. Evaluation of the injury mechanisms will be addressed for the specific injuries claimed by Ms. Miller.

Cervical Spine

According to Ms. Miller's medical records, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injury is causally related to the lateral impact event. There was no hyperextension mechanism present in the subject incident, there would only be right lateral bending and slight forward flexion. The cervical spine is extremely tolerant to inertial loading which results in lateral bending. A simple explanation for this is that the body has a built-in head restraint. The head is limited in lateral bending by contact of the head to the shoulder and in flexion by contact with the chest. Live human subjects have regularly been exposed to g levels up to approximately 9.0g in lateral bending and 16.0g in forward flexion with no acute trauma, only transient, short term soreness.[23] The subject incident had a nominal acceleration of 2.9g. Ms. Miller would not have been exposed to any loading or motion outside of the range of human tolerance. There was no injury mechanism present in the subject incident to account for Ms. Miller's claimed cervical injuries. As stated previously, Ms. Miller regularly receives loading that exceeds the acceleration to her body in the subject incident.

Additionally, researchers such as Zaborowski and Ewing have conducted several investigations that exposed human volunteers to lateral impact accelerations.[24,25,26,27] In response to these tests, physical complaints were transient in nature and none of the participants sustained or reported any cervical spine injuries. Fugger et al.[28] conducted lateral impacts with human volunteers. Physical complaints following these tests were noted following five tests, but complaints were transient in nature and consisted of back pain or slight headache that lasted a few minutes. Lateral impact research by Bailey et al.[29] again demonstrated that human volunteers sustained comparable severity lateral impacts without the onset of cervical spine injuries. These data are consistent with safe human exposure guidelines to lateral impact accelerations.[30,31]

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23 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

24 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact with Lap Belt Only (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

25 Zaborowski, A.B. (1964). Lateral Impact Studies: Lap Belt Shoulder Harness Investigations (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

26 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

27 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

28 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

29 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

30 Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

31 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance. As the subject incident did not create the required injury mechanism and did not induce force magnitudes that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical injuries of Ms. Miller cannot be made.

Thoracic and Lumbar Spine

According to Ms. Miller's medical records, there were findings consistent with a thoracic and lumbar sprain/strain.

There is no reason to assume that the claimed thoracic and lumbar injuries are causally related to the lateral impact event. In a lateral impact event of the type seen here the pelvis, thoracic and lumbar spines of an occupant are limited in motion by the restraint system. The seatbelt would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatbelt system would also distribute the restraint forces over the torso and hips, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The seatbelt system would not allow for hyperflexion of Ms. Miller's thoracic and lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit forward with little flexion, unless one portion of the spine is supported with another portion unsupported. There would be a greater force and movement on Ms. Miller's thoracic and lumbar spine when she sits down in a chair than what was produced in the subject incident.

Several investigators have considered the human response to lateral impacts. Research by Zaborowski,[34] subjected human volunteers restrained with only a lap belt to lateral impacts. The accelerations utilized during this investigation exceeded that of the subject incident and no permanent physiological changes were noted with physical complaints limited to minor or moderate transient pain. A follow up study again subjected human volunteers to lateral impacts with acceleration levels that exceeded that associated with the subject incident.[35] No permanent physiological changes were reported and minor complaints were limited to neck muscle soreness that resolved within a few days. Ewing et al.[36] subjected human volunteers to simulated side

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[32] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

[33] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

[34] Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact with Lap Belt Only (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

[35] Zaborowski, A.B. (1964). Lateral Impact Studies: Lap Belt Shoulder Harness Investigations (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

[36] Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

impacts with acceleration levels greater than associated with the subject incident. No physical complaints were reported in response to these tests. Further work by Ewing et al.,[37] subjected human volunteers to over one hundred simulated side impacts with acceleration levels greater than those associated with the subject incident. Again, no physical complaints were reported in response to these tests. Fugger et al.[38] conducted lateral impact tests involving human volunteers. The acceleration levels again exceeded that associated with the subject incident. Physical complaints immediately after impact were noted following only five of the tests. These complaints were transient in nature and consisted of back pain, and slight headache that lasted only a few minutes. All of the complaints came following the higher energy impacts. Bailey et al.[39] conducted lateral impact tests with human volunteers. Acceleration levels were greater than associated with the subject incident, and no physical symptoms were reported in response to these tests. Restrained human volunteers have also been regularly and repeatedly subjected to acceleration levels greater than that associated with the subject incident without acute lumbar or thoracic spine trauma.[40,41]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. The accelerations created by the subject incident were well within the limits of human tolerance. For these reasons, a causal link between the subject incident and the thoracic and lumbar injuries claimed by Ms. Miller cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On August 17, 2010, Ms. Sylvia Miller was the restrained driver of a 1991 Honda Civic when the right rear side was contacted by a 2002 Acura MDX.
2. The contact between the two vehicles is consistent with lateral impact for the Honda.
3. The change in velocity was less than 9.4miles per hour with accelerations less than 2.9g.
4. The acceleration experienced by Ms. Miller was within the limits of human tolerance and the personal tolerance levels of Ms. Miller based on an engineering analysis of Ms. Miller's physical activities and were comparable to that experienced during various daily activities.

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37 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

38 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

39 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

40 Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

41 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

5. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in a rightward and slightly forward motion of Ms. Miller's body relative to the interior of the vehicle. Any motion would have been well within the normal range of motion and tolerance levels of Ms. Miller and the protection afforded by the available restraint system.
6. There is no causal link between the reported cervical spine injuries of Ms. Miller and this reported collision. Ms. Miller experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed cervical injury was not present in the subject incident.
7. There is no causal link between the reported thoracic and lumbar spine injuries of Ms. Miller and this reported collision. Ms. Miller's thoracic and lumbar spine experiences motion and loading on a daily basis greater than that experienced in this incident.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
Probst 14
5-23-17

October 19, 2011

Lesli Wood, Esquire
Wilson, Smith, Cochran, Dickerson
901 Fifth Ave., Suite 1700
Seattle, WA 98164-2050

Re: *Khan, Mudassir v. Laura Paton*
Claim No.: 0292293020101026
ARCCA Case No.: 3808-013

Dear Ms. Wood:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Mudassir Khan. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on January 2, 2009, Mr. Mudassir Khan was the restrained driver of a 1987 Mazda B2000 Truck traveling along a freeway in Washington. Ms. Laura Paton was the driver of a 1990 Honda Civic traveling in the lane to the right of the Mazda. According to the available documents, the Honda merged left causing a collision. As a result, the left front of the incident Honda contacted the right rear side of the subject Mazda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Six (6) color photographic reproductions of the subject 1987 Mazda B2000
- Six (6) color photographic reproductions of the incident 1990 Honda Civic
- Geico repair estimate for the subject vehicle 1987 Mazda B2000 [January 7, 2009]
- Medical Records pertaining to Mudassir Khan
- VinLink data sheet for the subject 1987 Mazda B2000
- Expert AutoStats data sheets for a 1987 Mazda B2000
- Expert AutoStats data sheets for a 1990 Honda Civic

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Khan claims were caused by the subject incident;

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Khan was occupying;
3. Determine Mr. Khan's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Khan's response to the subject incident;
5. Evaluate Mr. Khan's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Khan has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Mazda B2000 and incident Honda Civic in association with accepted engineering methodologies. According to the available documents, the subject incident was a sideswipe impact with snagging between the Mazda and the Honda, where the primary points of impact to the incident Honda and the subject Mazda were to the left front and right rear side, respectively.

The damage estimate of the subject Mazda B2000 indicated damage primarily to the rear bumper assembly, right side panel, right rear molding, and right corner post; which is consistent with the photographic reproductions of the subject Mazda. The photographic reproductions of the incident Honda indicate damage to the front bumper cover, left fender, left headlight and left turn signal.

ARCCA, Inc. has an ongoing bumper test project. A testing protocol was developed to evaluate the bumper characteristics of vehicles. This testing protocol subjected the bumper assembly to a quasi-static load and quantified the force-deflection relationship and failure level. The methodology and analysis utilized is well accepted and established within the engineering community as documented within the technical literature.[11]

[11] Beer, F.P., and Johnston, E.R., (1992). Mechanics of Materials, Second Edition. New York, McGraw-Hill Inc.

From the results, it was determined using standard engineering practices that a full sized SUV would have been exposed to an acceleration of less than or comparable to 1g under loading conditions that caused the bumper and bumper assembly to structurally fail. Therefore, the laws of physics dictate that the subject Mazda in which Mr. Khan was seated during the subject incident was exposed to an acceleration level less than 1g. Using the shape of a haversine, and the pulse width of 200 ms, the Delta-V associated with a vehicle peak acceleration of 1g is 2.3 mph.[12] As a result, had the forces associated with the subject incident been sufficient to generate vehicle motion, the subject Mazda would have been subjected to a Delta-V of less than or comparable to 2.3 mph.

The acceleration experienced due to gravity is 1g. This means that Mr. Khan experiences 1g of loading while in a sedentary state. Therefore, Mr. Khan experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Khan in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Mazda B2000 in which Mr. Khan was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Khan's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Khan was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Khan's principle direction of motion would be forward and rightward, relative to the subject vehicle.

The laws of physics dictate that when the incident Honda Civic contacted the right rear side of the subject Mazda B2000, had there been enough energy transferred to initiate motion, the Mazda would have been decelerated and pushed leftward causing Mr. Khan's body to move forward and rightward relative to the interior of the subject vehicle. The three-point restraint that

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12 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M., (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

Mr. Khan was reportedly wearing would have locked when the vehicle accelerations exceeded 0.7g,[15] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Mr. Khan, as well as the passive muscle resistance of his arms would have acted in conjunction with his three-point restraint to limit body motion. Provided the low accelerations of the subject incident, and the supports described, the bodily response of Mr. Khan would have been limited to within normal physiological limits

Findings:

1. On January 2, 2009, Mr. Mudassir Khan was the belted driver of a 1987 Mazda B2000 Truck that was contacted in the right rear side at low speed.
2. The change in velocity was less than 2.3 miles-per-hour with peak accelerations less than 1.0g.
3. The acceleration experienced by Mr. Khan was within the limits of human tolerance, the personal tolerance levels of Mr. Khan and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Khan was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[16,17]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

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15 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

16 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

17 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

As described previously, the vehicle interaction would have caused rearward and leftward acceleration of the subject Mazda. Had the forces generated been sufficient to overcome Mr. Khan's muscle reaction forces, his body would have moved forward and rightward relative to the Mazda's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Mazda. Mr. Khan's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. The cervical spine is extremely tolerant to forward and lateral accelerations due to built in anatomical constraints. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[18] A kinematic analysis of Mr. Khan's response to the subject incident demonstrated that his overall head motion would have been relatively minimal.[19,20] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[21] As a result, Mr. Khan's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[22]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[23] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[24] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine injury potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical injury are

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18 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

19 Araszewski, M., Roenitz, E., and Toor, A., (1999). Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

20 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004). Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

21 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

22 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

23 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

24 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

greater that that associated with the subject incident.[25,26] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[27] None of the participants reported any chronic cervical injuries. Arbogast et al.[28] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[29] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[30,31] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries and long term sequelae of Mr. Khan cannot be made.

Thoracic and Lumbar Spine
According to the available documents, there were findings consistent with a thoracic, lumbar and lumbosacral sprain/strain.

In this type of collision, the motion of Mr. Khan's thoracic and lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Mr. Khan's muscle reaction forces, his body would have moved forward and rightward relative to the Mazda's interior. As described previously, Mr. Khan was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited his forward body excursion.[32] Therefore, Mr. Khan's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion

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25 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

26 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

27 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

28 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

29 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

30 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

31 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

32 Code of Federal Regulations, Federal Motor Vehicle Safety Standard, Title 49, Part 571, Section 209.

of Mr. Khan's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[33] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[34] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[35] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[36] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[37] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic injury. The subject incident had a peak acceleration below 1.0g. Mr. Khan's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and acute thoracic, lumbar, and lumbosacral spine injuries of Mr. Khan cannot be made.

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33 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

34 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

35 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

36 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

ARCCA

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On January 2, 2009, Mr. Mudassir Khan was the belted driver of a 1987 Mazda B2000 that was contacted in the right rear side at low speed.
2. The severity of the subject incident was consistent with a Delta-V less than 2.3 miles-per-hour with peak acceleration less than 1.0g for the subject 1987 Mazda B2000 in which Mr. Khan was seated.
3. The acceleration experienced by Mr. Khan was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupant's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Mr. Khan's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Mr. Khan's claimed thoracic, lumbar and lumbosacral injuries. As such, a causal relationship between the subject incident and the thoracic, lumbar and lumbosacral injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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EXHIBIT
Probst 15
5-23-17
PENGAD 800-631-6989

December 6, 2011

Mary Evenson
Safeco Insurance Company
P.O. Box 515097
Los Angeles, CA 90051

Cc: Jason Hoeft, Esquire

Re: *Smart, Arianna v. Lois Broadway*
Claim No.: 122561793018
ARCCA Case No.: 3271-076

Dear Ms. Evenson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Arianna Smart. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

Incident Description:

According to the available documents, on April 8, 2009, Ms. Arianna Smart was the restrained driver of a 2009 Pontiac Vibe traveling southbound on 212th Street in Edmonds, Washington. Ms. Lois Broadway was the restrained driver of a 2004 Volvo XC90 traveling southbound on 212th Street directly behind the Pontiac Vibe. According to the available documents, the Pontiac Vibe stopped for a red light and the Volvo XC90 failed to stop in time. As a result, the front bumper of the incident Volvo contacted the rear of the subject Pontiac. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Three (3) color photographic reproductions of the subject vehicle 2009 Pontiac Vibe
- Auto Nation Collision Center–Seattle repair estimate for the subject vehicle 2009 Pontiac Vibe [April 9, 2009]
- Safeco Insurance of Illinois repair estimate for the incident vehicle 2004 Volvo XC90 [April 22, 2009]
- Medical Records pertaining to Arianna Smart
- Deposition transcript of Arianna Smart, January 14, 2011
- Plaintiff's Answers to Defendant's First Set of Interrogatories and Requests For Production, *Arianna Smart v. Lois Broadway and John Doe Broadway* [June 30, 2010]
- VinLink data sheet for the subject 2009 Pontiac Vibe
- Expert AutoStats data sheets for a 2009 Pontiac Vibe
- VinLink data sheet for the incident 2004 Volvo XC90
- Expert AutoStats data sheets for a 2004 Volvo XC90

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Smart claims was caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Smart was occupying;
3. Determine Ms. Smart's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Smart's response to the subject incident;

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

5. Evaluate Ms. Smart's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Smart has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
- Concussion

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Pontiac Vibe and incident Volvo XC90 in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Pontiac and the Volvo, where the primary points of impact to the incident Volvo and the subject Pontiac were to the front and rear, respectively.

The damage estimate of the subject Pontiac Vibe indicated damage primarily to the rear bumper cover, which is consistent with the reviewed photographic reproductions. The damage estimate of the incident Volvo XC90 indicated there was no damage to the vehicle.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Volvo can be used to resolve the loads sustained by the subject Pontiac. That is, the forces sustained by the incident Volvo are equal and opposite to those of the subject Pontiac.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Volvo XC90, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2003 Volvo XC90, essentially the same vehicle as a 2004 Volvo XC90. In a five mile-per-hour frontal impact into a flat barrier the test Volvo XC90 sustained damage. There was no damage found to the front of the incident Volvo XC90. Thus, because the test Volvo XC90 in the IIHS frontal impact test sustained much less damage, the severity of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Conservation of Momentum indicates that for a 5 mile-per-hour change in velocity for the XC-90 the subject Pontiac will experience a change of velocity of 7.5 miles-per-hour, Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of 7.5 miles-per-hour for the subject Pontiac Vibe. Using an acceleration pulse with the shape of a haversine and a pulse width of 150 milliseconds, the average acceleration associated with a 7.5 mph Delta-V

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

is 2.3g.[12,13,14] As a result, the Pontiac in which Ms. Smart was seated during the rear impact event, was exposed to a Delta-V less than 7.5 mph with an effective acceleration level less than 2.3g.

The acceleration experienced due to gravity is 1g. This means that Ms. Smart experiences 1g of loading while in a sedentary state. Therefore, Ms. Smart experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Smart in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[15] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[16]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Pontiac in which Ms. Smart was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Smart's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Smart was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Smart's principle direction of motion would be rearward, relative to her vehicle.

The laws of physics dictate that when the incident Volvo contacted the rear of the subject Pontiac, had there been enough energy transferred to initiate motion, the Pontiac would have been pushed forward causing Ms. Smart's seat to move forward relative to her body, which would result in Ms. Smart moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Smart and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[17,18,19] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Smart would have been limited to well within the range of normal physiological limits.

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12 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

13 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts (SAE 970120). Warrendale, PA. Society of Automotive Engineers.

14 Heinrichs, B.E., Lawrence, J.M., Allin, B.D., et al. (2001). Low-Speed Impact Testing of Pickup Truck Bumpers (SAE 2001-01-0893). Warrendale, PA. Society of Automotive Engineers.

15 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

16 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

17 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

18 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

19 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

Findings:

1. On April 8, 2009, Ms. Arianna Smart was the belted driver of a 2009 Pontiac Vibe that was contacted in the rear at low speed.
2. The change in velocity was less than 7.5 miles-per-hour with average accelerations well below 2.3g.
3. The acceleration experienced by Ms. Smart was within the limits of human tolerance, the personal tolerance levels of Ms. Smart and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Smart was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[20,21]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick, tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Pontiac would be pushed forward and Ms. Smart would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

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[20] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[21] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Examination of an exemplar 2009 Pontiac Vibe showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.5 inches in the "full down" position and 33.75 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Smart's age (26 years), height (61-62 inches) and weight (165-180 lbs), Ms. Smart has a normal seated height of 31.6-32.0 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Smart and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[22] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[23] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[24] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[25] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Smart in the subject incident. The subject incident had an average acceleration below 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[26,27] Ms. Smart would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[28,29] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head

22 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

23 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

24 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

25 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

26 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

27 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

29 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported acute cervical spine injuries of Ms. Smart cannot be made.

Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[30] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[31] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[32] The subject incident had an average acceleration significantly below 2.3g. Ms. Smart's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[33,34,35,36,37] Previous

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30 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

31 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

32 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

33 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

34 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

35 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

36 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[38] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[39]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Smart a causal link between the subject incident and claimed acute thoracic and lumbar injuries cannot be made.

Concussion

Following the subject incident, Ms. Smart was reported to have sustained a concussion. There was no reported loss of consciousness and Ms. Smart thought she may have hit her head, however, there was no reported evidence of head trauma.

A brain injury without skull fracture is classified as a mild diffuse brain injury or concussion.[40,41] Acute onset of concussion requires that the brain tissue be stretched and/or strained beyond physiological limits.[42,43,44,45] The injury mechanism required to cause a concussion is loading to the brain that causes stretching and/or straining of the brain tissue beyond physiological limits. These injuries are associated with substantial impulsive or impact loads applied to the head.[46]

The subject incident lacked the energy necessary to cause Ms. Smart's diagnosed concussion.[47,48] As described previously, had the loads associated with the subject incident been sufficient to overcome Ms. Smart's muscle reaction forces, her body would have moved rearward relative to the Pontiac's interior. The seatback structure and three-point restraint that Ms. Smart was reportedly wearing would have limited her body motion. During this response, Ms. Smart's head would have been subjected to some degree of rearward

37 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

38 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

39 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

40 Gennarelli, T.A. (1982) "Impact Injury Caused by Linear Acceleration: Mechanisms, Prevention, and Cost." NATO AGARD Conference 1-9.

41 Viano, D.C. Biomechanics of Head Injury – Toward a Theory Linking Head Dynamic Motion, Brain Tissue Deformation and Neural Trauma (SAE 881708). Warrendale, PA. Society of Automotive Engineers.

42 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

43 Gennarelli, T.A., (2003) "Mechanisms of Brain Injury." Journal of Emergency Medicine 11: 5-11.

44 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." Journal of Trauma 66(2): 309-315.

45 Mclean, A.J., (1995) "Brain Injury without Head Impact?" Journal of Neurotrauma 12(4): 621-625.

46 Goldsmith, W., (2001) "The State of Head Injury Biomechanics: Past, Present, and Future: Part 1." Critical Reviews in Biomedical Engineering 29 (5 & 6): 441-600.

47 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." Journal of Trauma 66(2): 309-315.

48 Mclean, A.J., (1995) "Brain Injury without Head Impact?" Journal of Neurotrauma 12(4): 621-625.

extension upon impact and potential head contact with the headrest. However this possible head contact would not have generated enough energy to cause injury or trauma to the head. [49]

The Head Injury Criterion (HIC) has been adopted by the United States federal government as the standard criterion for the determination of risk of a head injury for the Federal Motor Vehicle Safety Standards (FMVSS). In brief, HIC is calculated from resultant accelerations at the center of gravity of the head (based upon three orthogonal directions) that are optimized over a duration of impact.

FMVSS 201, titled Occupant Protection in Interior Impact, specifies requirements to afford impact protection for occupants.[50] More specifically, FMVSS 201 is related to the likelihood of injury resulting from occupant head contact with the interior of a vehicle. FMVSS 201 dictates that when the interior of a vehicle is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, HIC(d), an acronym for Head Injury Criterion (dummy), should not exceed 1000 for any two points in time during the impact which are separated by not more than a 36 millisecond time interval. FMVSS 201 further dictates that when a seatback is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, the deceleration of the headform shall not exceed 80g continuously for more than 3 milliseconds. This requirement is consistent with previous research published by Ono et al. that investigated the human head impact tolerance and the threshold for concussion.[51]

FMVSS 202a, titled Head Restraints, specifies new requirements for head restraints to reduce the frequency and severity of head and neck injuries in rear-end and other collisions.[52] More specifically, FMVSS 202a specifies that during dynamic rear impact testing at accelerations of approximately 9.4g, HIC should not exceed 500 for any two points in time during the impact which are separated by not more than a 15-millisecond time interval.

This subject incident had an average acceleration below 2.3g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[53,54] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g

Based upon the review of the available incident data and the results cited in the technical literature, the subject incident created accelerations that were well within human tolerance and were comparable to accelerations applied during daily activities. Therefore, the subject incident was within Ms. Smart's personal tolerance. In addition, the loads associated with the subject incident were not applied in the proper manner or with sufficient magnitude to generate the injury mechanism necessary for her diagnosed brain injury. As this crash event did not apply loads of sufficient magnitude to exceed Ms. Smart's personal tolerance and the necessary injury mechanism was not created, causation between the subject incident and her diagnosed concussion cannot be established

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49 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

50 Federal Motor Vehicle Safety Standard 571.201. Occupant Protection in Interior Impact.

51 Ono, K., Kikuchi, A., et al. (1980). Human Head Tolerance to Sagittal Impact Reliable Estimation Deduced from Experimental Head Injury Using Subhuman Primates and Human Cadaver Skulls. (SAE 801303). Warrendale, PA, Society of Automotive Engineers.

52 Federal Motor Vehicle Safety Standard 571.202a. Head Restraints.

53 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

54 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

ARCCA

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 8, 2009, Ms. Arianna Smart was the belted driver of a 2009 Pontiac Vibe that was contacted in the rear at low speed.

2. The severity of the subject incident was consistent with a Delta-V well below 7.5 miles-per-hour with an average acceleration well below 2.3g for the subject 2009 Pontiac Vibe in which Ms. Smart was seated.

3. The acceleration experienced by Ms. Smart was within the limits of human tolerance and comparable to that experienced during various daily activities.

4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Smart's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits

5. There is no injury mechanism present in the subject incident to account for Ms. Smart's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.

6. There is no injury mechanism present in the subject incident to account for Ms. Smart's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

7. The injury mechanism required to cause brain injury to Ms. Smart was not created during the subject incident. As such, causation between the subject incident and the claimed concussion to Ms. Smart cannot be established.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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December 8, 2011

Lisa Liekhus, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re: *Hinds, Joleen v. Paula Lyckman*
Claim No.: 497680124008
ARCCA Case No.: 2107-558

Dear Ms. Liekhus:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Joleen Hinds. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on November 25, 2009, Ms. Joleen Hinds was the restrained driver of a 1998 Ford Escort traveling westbound on East Front Street in Port Angeles, Washington. Ms. Paula Lyckman was the restrained driver of a 2005 Kia Sorento traveling on East Front Street directly behind the Ford Escort. Ms. Megan Zumbuhl was the restrained driver of a 1990 Volkswagen Cabriolet traveling on East Front Street directly in front of the Ford Escort. According to the available documents, the Volkswagen and Ford stopped for traffic and the Ford was struck from behind by the incident Kia. As a result, the front bumper of the incident Kia contacted the rear of the subject Ford causing the front of the Ford to strike the incident Volkswagen. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No.: 3201345
- One hundred thirty-nine (139) color photographic reproductions of the subject 1998 Ford Escort
- Nine (9) color photographic reproductions of the incident 2005 Kia Sorento
- Twelve (12) color photographic reproductions of the incident 1990 Volkswagen Cabriolet
- Inspection of the subject vehicle 1998 Ford Escort by Brad Probst [August 4, 2011]
- North American Claim Solution repair estimate for the incident 2005 Kia Sorento [January 18, 2010]
- Recorded Statement Summary Report of Paula Lyckman [June 2, 2010]
- Medical Records pertaining to Joleen Hinds
- VinLink data sheet for the subject 1998 Ford Escort
- Expert AutoStats data sheets for a 1998 Ford Escort
- Expert AutoStats data sheets for a 1997 Ford Escort
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1997 Ford Escort
- VinLink data sheet for the incident 2005 Kia Sorento
- Expert AutoStats data sheets for a 2005 Kia Sorento
- Expert AutoStats data sheets for a 2003 Kia Sorento
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2003 Kia Sorento
- VinLink data sheet for the incident 1990 Volkswagen Cabriolet
- Expert AutoStats data sheets for a 1990 Volkswagen Cabriolet

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Hinds claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Hinds was occupying;
3. Determine Ms. Hinds's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Hinds's response to the subject incident;
5. Evaluate Ms. Hinds's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Hinds has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain

[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

[7] Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

- Thoracic, Lumbar, Lumbosacral, and Sacroiliac Spine
  - Sprain/strain
  - L3-4 minimal left foraminal disc herniation
  - Exacerbation of lumbar L4-5 and L5-S1 disc injuries

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Ford Escort and incident Kia Sorento in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Ford and the Kia, where the primary points of impact to the incident Kia and the subject Ford were to the front and rear, respectively.

The damage estimate of the subject Ford indicated damage primarily to the rear bumper assembly and rear body panel, which is consistent with the reviewed photographic reproductions and my vehicle inspection. The damage estimate of the incident Kia indicated damage primarily to the front bumper cover and fog lamps, which is consistent with the reviewed photographic reproductions.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Ford Escort, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 1997 Ford Escort, essentially the same vehicle as the subject Escort, in a five mile-per-hour rear impact into a flat barrier. The test Ford sustained damage to the rear body panel, rear bumper assembly and rear reinforcement bumper. The primary damage to the subject Ford was to the rear bumper assembly and rear body panel. Thus, because the test Ford in the IIHS rear impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Additionally, the IIHS tested a 2003 Kia Sorento, essentially the same vehicle as the incident 2005 Sorento, in a five mile-per-hour frontal impact into a flat barrier. The test Kia sustained damage to the front bumper cover, front lower bumper absorber, front lower bumper reinforcement/frame crossmember, front upper unibody crossmember, lower right headlamp mounting bracket and grille. The primary damage to the incident Kia was to the front bumper cover and fog lamps. Thus, because the test Kia in the IIHS frontal impact test sustained more damage, the severity of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Ford Escort. Using an acceleration pulse

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[12] By the laws of physics, the average acceleration experienced by the subject Ford Escort in which Ms. Hinds was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Hinds experiences 1g of loading while in a sedentary state. Therefore, Ms. Hinds experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Hinds in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Ford in which Ms. Hinds was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Hinds's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Hinds was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Hinds's principle direction of motion would be rearward, relative to her vehicle. The available documents indicate that Ms. Hinds was thrown forward then backward due to the subject incident.

This is contrary to the actual motions of the incident. The laws of physics dictate that when the incident Kia contacted the rear of the subject Ford, had there been enough energy transferred to initiate motion, the Ford would have been pushed forward causing Ms. Hinds's seat to move forward relative to her body, which would result in Ms. Hinds

12 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Hinds and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Hinds would have been limited to well within the range of normal physiological limits.

Findings:

1. On November 25, 2009, Ms. Joleen Hinds was the belted driver of a 1998 Ford Escort that was contacted in the rear at low speed.
2. The change in velocity was comparable to 5 miles-per-hour with average accelerations comparable to 1.5g.
3. The acceleration experienced by Ms. Hinds was within the limits of human tolerance, the personal tolerance levels of Ms. Hinds and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Hinds was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?

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15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection **5**(1): 55-66.

18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[20]

Cervical Spine

According to the available documents there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford would be pushed forward and Ms. Hinds would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a “whiplash” injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1998 Ford Escort showed that the nominal height of the driver’s seat with an unoccupied, uncompressed seat is 26.75 inches in the “full down” position and 29.25 inches in the “full up” position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric

[20] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

regression of Ms. Hinds's age (31 years), height (67 inches) and weight (200 lbs), Ms. Hinds has a normal seated height of 34.1 inches. Additionally the available documents indicate that Ms. Hinds's head came into contact with the headrest. Thus the seat is tall enough to have prevented hyperextension of Ms. Hinds and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[21] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[22] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[23] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[24] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Hinds in the subject incident. The subject incident had an average acceleration comparable to 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[25,26] Ms. Hinds would not have been exposed to any loading or motion outside of her personal tolerance levels.

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21 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

22 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

23 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* **6**:366-375.

24 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* **29**:979-987.

25 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* **42**: 25-30.

26 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[27,28] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Hinds cannot be made.

Thoracic, Lumbar, Lumbosacral, Sacroiliac Spine

According to a lumbar MRI dated August 23, 2010, there were findings consistent with a L3-4 minimal left foraminal disc herniation, L4-5 mild posterior to right foraminal disc herniation and a L5-S1 small posterior disc herniation. According to a lumbar MRI dated September 21, 2006, there were findings consistent with a L4-5 broad based disc protrusion and L5-S1 mild disc space narrowing with a disc extrusion. Additionally, according to the other available documents, there were findings consistent with an exacerbation of prior L4-5 and L5-S1 disc injuries along with a thoracic, lumbar, lumbosacral and sacroiliac sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

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27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[29] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[30] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[31] The subject incident had an average acceleration comparable to 1.5g. Ms. Hinds's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[32,33,34,35,36] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[37] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[38]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic spine. Finally, the forces created by the incident were well within the limits of human tolerance for the

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29 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

30 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

31 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

32 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

33 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

34 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* **7**(3): 184-191.

35 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* **16**: 549-559.

36 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

37 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

38 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Hinds, a causal link between the subject incident and claimed injuries and/or exacerbated thoracic, lumbar, lumbosacral and sacroiliac injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On November 25, 2009, Ms. Joleen Hinds was the belted driver of a 1998 Ford Escort that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with an average acceleration comparable to 1.5g for the subject 1998 Ford Escort in which Ms. Hinds was seated.
3. The acceleration experienced by Ms. Hinds was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Hinds's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Hinds's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Hinds's claimed acute and/or exacerbated thoracic, lumbar, lumbosacral and sacroiliac spine injuries. As such, a causal relationship between the subject incident and the thoracic, lumbar, lumbosacral and sacroiliac injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

ARCCA, INCORPORATED
4314 ROOSEVELT WAY NE
SEATTLE, WA 98105
PHONE 877-942-7222 **FAX** 206-547-0759
www.arcca.com

January 9, 2012

Eric Chavez, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *An, Sandra v. Delfina Casaretto*
Claim No.: 264144154041
ARCCA Case No.: 3271-126

Dear Mr. Chavez:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Sandra An. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on December 14, 2010, Ms. Sandra An was the restrained driver of a 2006 Lexus RX 400h traveling westbound on SW 320th Street in Federal Way, Washington. Ms. Michelle Smith was the driver of a 2002 Honda Accord traveling on SW 320th Street directly behind the Lexus. According to the available documents, the Lexus was stopped for traffic and was contacted from behind by the incident Honda. As a result, the front bumper of the incident Honda contacted the rear of the subject Lexus. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Federal Way Police Department Traffic Incident Report, Case No. 10-16218
- Ten (10) color photographic reproductions of the subject vehicle 2006 Lexus RX 400h
- Two (2) color photographic reproductions of the incident vehicle 2002 Honda Accord
- Safeco Insurance Company of Illinois appraisal for the subject 2006 Lexus LX 400h [December 22, 2010]
- Maaco Collision Repair & Auto Painting repair estimate for the incident 2002 Honda Accord [December 16, 2010]
- Medical Records pertaining to Sandra An
- VinLink data sheet for the subject 2006 Lexus RX 400h
- Expert AutoStats data sheets for a 2006 Lexus RX 400h
- Expert AutoStats data sheets for a 2004 Lexus RX 330
- Expert AutoStats data sheets for a 2007 Lexus RX 350
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2004 Lexus RX 330
- Expert AutoStats data sheets for a 2002 Honda Accord

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. An claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. An was occupying;
3. Determine Ms. An's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. An's response to the subject incident.
5. Evaluate Ms. An's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. An has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Lexus and incident Honda in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Lexus and the Honda, where the primary points of impact to the incident Honda and the subject Lexus were to the front and rear, respectively.

The damage estimate of the subject Lexus indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions. The damage estimate of the incident Honda indicated damage primarily to the front bumper cover, hood, and radiator support; which is consistent with the reviewed photographic reproductions.

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7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Lexus RX 400h, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2004 Lexus RX 330, essentially the same vehicle as the subject 2006 Lexus RX 400h, in a five mile-per-hour rear impact into a flat barrier. The test Lexus sustained damage to the rear bumper reinforcement, and the left and right rear body panel frame sidemember ends. The primary damage to the subject Lexus was to the rear bumper cover. Thus, because the test Lexus in the IIHS rear impact test sustained more damage, the severity of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed below the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Lexus RX 400h. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[12] By the laws of physics, the average acceleration experienced by the subject Lexus in which Ms. An was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. An experiences 1g of loading while in a sedentary state. Therefore, Ms. An experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. An in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, prior to the subject incident Ms. An was able to landscape, ice skate, snowboard, perform housing repairs, and was a very active and physical person. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

[13] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

[14] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Lexus in which Ms. An was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. An's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. An was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. An's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. An's head was turned to the right prior to impact.

The laws of physics dictate that when the incident Honda contacted the rear of the subject Lexus, had there been enough energy transferred to initiate motion, the Lexus would have been pushed forward causing Ms. An's seat to move forward relative to her body, which would result in Ms. An moving rearward relative to the interior of the subject vehicle. This interaction between Ms. An and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. An would have been limited to well within the range of normal physiological limits.

Findings:

1. On December 14, 2010, Ms. Sandra An was the belted driver of a 2006 Lexus RX 400h that was contacted in the rear at low speed.
2. The change in velocity was less than 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Ms. An was within the limits of human tolerance, the personal tolerance levels of Ms. An and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. An was well within the limits of human tolerance and well below the acceleration levels that she likely

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15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection **5**(1): 55-66.

experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Lexus would be pushed forward and Ms. An would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2007 Lexus RX 350, essentially the same vehicle as a 2006 Lexus RX 400h, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30.75 inches in the "full down" position and 33.0 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. An's age (33 years), height (62 inches) and weight (120 lbs), Ms. An has a normal seated height of 31.8 inches. Thus the seat is tall enough to have prevented

18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

hyperextension of Ms. An and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[20] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[21] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[22] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[23] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. An in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[24,25] Ms. An would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[26,27] accelerations of the head and spinal structures were measured during activities of daily

20 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

21 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

22 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* **6**:366-375.

23 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* **29**:979-987.

24 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* **42**: 25-30.

25 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

26 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. An cannot be made.

Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[28] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[29] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[30] The subject incident had an average acceleration less than 1.5g. Ms. An's thoracic and lumbar spine would not

[28] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[29] Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[30] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

have been exposed to any loading or motion outside of the range of her personal tolerance levels.[31,32,33,34,35] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[36] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[37]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. An, a causal link between the subject incident and claimed thoracic and lumbar spine injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 14, 2010, Ms. Sandra An was the belted driver of a 2006 Lexus RX 400h that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 2006 Lexus RX 400h in which Ms. An was seated.
3. The acceleration experienced by Ms. An was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. An's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

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[31] Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[32] Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[33] Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* **7**(3): 184-191.

[34] Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* **16**: 549-559.

[35] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[36] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

[37] Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

5. There is no injury mechanism present in the subject incident to account for Ms. An's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account Ms. An's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

EXHIBIT
Probst 16
5-23-17 VNY

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January 10, 2012

William Fuld, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

RECEIVED
JAN 10 2012
LAW OFFICES OF LEONARD SEMENEA, P.S.

Re: *Corner, Ulibee Parker v. Adam Lusardo*
Claim No.: 893989273007
ARCCA Case No.: 2107-605

Dear Mr. Fuld:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Ulibee Corner. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

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3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on July 7, 2008, Ms. Ulibee Comer was the restrained driver of a 2003 Toyota Matrix traveling on the Exit 5 on ramp to I-405 northbound in Renton, Washington. Mr. Adam Lusardo was the driver of a 2004 Hyundai Santa Fe traveling on the Exit 5 on ramp directly behind the Toyota. According to the available documents, the Toyota was stopped for traffic and was struck from behind by the incident Hyundai. As a result, the front bumper of the incident Hyundai contacted the rear of the subject Toyota. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Fifteen (15) color photographic reproductions of the subject vehicle 2003 Toyota Matrix
- Seven (7) color photographic reproductions of the incident vehicle 2004 Hyundai Santa Fe
- Safeco Insurance Company of Illinois repair estimate for the subject 2003 Toyota Matrix [July 18, 2008]
- Safeco Insurance Company of Illinois Supplement of Record 1 with Summary for the subject 2003 Toyota Matrix [September 3, 2008]
- Review of Interrogatory Responses [March 16, 2011]
- Deposition Transcript of Ulibee Parker Comer [September 23, 2011]
- Medical Records pertaining to Ulibee Comer
- VinLink data sheet for the subject 2003 Toyota Matrix
- Expert AutoStats data sheets for a 2003 Toyota Matrix
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2003 Toyota Matrix
- Expert AutoStats data sheets for a 2004 Hyundai Santa Fe

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

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1. Identify the injuries that Ms. Comer claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Comer was occupying;
3. Determine Ms. Comer's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Comer's response to the subject incident.
5. Evaluate Ms. Comer's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Comer has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Soft tissue injuries
- Thoracic and Lumbar Spine
  - Soft tissue injuries

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota and incident Hyundai in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Toyota and the Hyundai, where the primary points of impact to the incident Hyundai and the subject Toyota were to the front and rear, respectively.

The damage estimate of the subject Toyota indicated damage primarily to the rear bumper cover and left outer spoiler; which is consistent with the reviewed photographic reproductions. The reviewed photographic reproductions of the incident Hyundai indicate damage to the front bumper cover and license plate.

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[7] Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Matrix, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested several cars of the same era from the same manufacturer as the subject vehicle as well as vehicles from other manufacturers. In a five mile-per-hour rear impact into a flat barrier the test vehicles all sustained damage varying from the rear bumper covers, rear reinforcement bars, and mounting brackets among other parts in some tests. The primary damage to the subject Toyota was to the rear bumper cover and left outer spoiler. Thus, because the test Toyota in the IIHS rear impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Toyota Matrix. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[12] By the laws of physics, the average acceleration experienced by the subject Toyota in which Ms. Corner was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Corner experiences 1g of loading while in a sedentary state. Therefore, Ms. Corner experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Corner in her daily life would have increased the loading to her body beyond the sedentary 1g. According to her testimony, prior to the subject incident Ms. Corner was able to volunteer at the pet shelter, work out, travel and perform her work duties. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

[13] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

[14] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota in which Ms. Corner was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Corner's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. Corner was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Corner's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. Corner testified that her body went forward, backward and then the seatbelt tightened.

This is contrary to the actual motions due to the incident, the laws of physics dictate that when the incident Hyundai contacted the rear of the subject Toyota, had there been enough energy transferred to initiate motion, the Toyota would have been pushed forward causing Ms. Corner's seat to move forward relative to her body, which would result in Ms. Corner moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Corner and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Corner would have been limited to well within the range of normal physiological limits.

Findings:

1. On July 7, 2008, Ms. Ulibee Corner was the belted driver of a 2003 Toyota Matrix that was contacted in the rear at low speed.
2. The change in velocity was comparable to 5 miles-per-hour with average accelerations comparable to 1.5g.
3. The acceleration experienced by Ms. Corner was within the limits of human tolerance, the personal tolerance levels of Ms. Corner and comparable to that experienced during various daily activities.

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15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Corner was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, which is a thick tough, fibrous tissue that connects bones together, by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to her testimony, Ms. Corner had complaints of cervical soft tissues injuries.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota would be pushed forward and Ms. Corner would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2003 Toyota Matrix showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.25 inches in the "full down" position and 34.0 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of

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18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Corner's age (29 years), and using the 95th percentile female height (69 inches) and weight (240 lbs), a 95th percentile female would have a normal seated height of 35.0 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Corner, if she is less than 95th percentile, and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[20] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[21] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[22] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[23] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Corner in the subject incident. The subject incident had an average acceleration comparable to 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[24,25] Ms. Corner would not have been exposed to any loading or motion outside of her personal tolerance levels.

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20 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

21 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

22 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

23 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

24 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

25 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[26,27] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported injuries and/or exacerbation of pre-existing injuries of Ms. Corner cannot be made.

Thoracic and Lumbar Spine

According to her testimony, Ms. Corner had complaints of thoracic and lumbar soft tissue injuries.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[28] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the

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[26] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

[27] Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

[28] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

Delta-V of the struck vehicle approximately 5 mph.[29] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[30] The subject incident had an average acceleration comparable to 1.5g. Ms. Corner's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[31,32,33,34,35] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[36] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[37]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Corner, a causal link between the subject incident and claimed injuries and/or exacerbation of pre-existing injuries cannot be made.

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29 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

30 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

31 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

32 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

33 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

34 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

35 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

36 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

37 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

ARCCA

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 7, 2008, Ms. Ulibee Corner was the belted driver of a 2003 Toyota Matrix that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with an average acceleration comparable to 1.5g for the subject 2003 Toyota Matrix in which Ms. Corner was seated.
3. The acceleration experienced by Ms. Corner was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Corner's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no injury mechanism present in the subject incident to account for Ms. Corner's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account Ms. Corner's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
Probst 17
5-23-12

February 3, 2012

Todd Reichert, Esquire
Mullin Law Group PLLC
101 Yesler Way, Suite 400
Seattle, WA 98104

Re: *Baccay, Cayetana v. F. Rodgers and Josh Livingston*
ARCCA Case No.: 3692-002

Dear Mr. Reichert:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Cayetana Baccay. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on August 27, 2008, Ms. Cayetana Baccay was the restrained right front passenger of a 1992 Honda Civic traveling northbound on Martin Luther King Jr. Way S in Seattle, Washington. Mr. John Livingston was the restrained driver of a 1996 Chevrolet C1500 that pulled in front of, perpendicular to, the subject Honda. According to the available documents, the incident Chevrolet entered the subject vehicle's lane of traffic and the Honda was unable to stop in time. As a result, the front of the subject Honda contacted the driver's side of the incident Chevrolet. The subject Honda driver's airbag deployed as a result of the impact and it was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No.: 2664022
- Six (6) color photographic reproductions of the incident vehicle 1996 Chevrolet C1500
- Plaintiff's First Supplemental Response to Defendants F. Rodgers Corporation and Joshua D. Livingston's First Set of Interrogatories and Request for Productions to Plaintiff Cayetana Baccay, *Cayetana Baccay vs. Joshua D. Livingston and Jane Doe Livingston and F. Rodgers Corporation and Isabelo Baccay* [January 13, 2012]
- Deposition Transcript of Cayetana Baccay [November 30, 2011]
- Deposition Transcript of Isabelo Baccay [September 2, 2011]
- Deposition Transcript of Joshua D. Livingston [September 2, 2011]
- Medical Records pertaining to Cayetana Baccay
- VinLink data sheet for the subject 1992 Honda Civic
- Expert AutoStats data sheets for a 1992 Honda Civic
- VinLink data sheet for the incident 1996 Chevrolet C1500
- Expert AutoStats data sheets for a 1996 Chevrolet C1500

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Baccay claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Baccay was occupying;
3. Determine Ms. Baccay's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Baccay's response to the subject incident.
5. Evaluate Ms. Baccay's personal tolerance in the context of their pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and their reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Baccay has reported the following injuries as a result of the subject incident:

- Thoracic and Lumbar Spine
  - Sprain/strain
  - L2-3, L3-4, L4-5 and L5-S1 mild endplate spondylitic changes with bulges

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject Honda Civic and incident Chevrolet C1500 in association with accepted engineering methodologies. According to the available documents, the subject incident was a frontal impact between the Honda Civic and the Chevrolet C1500, where the primary points of impact to the incident Chevrolet and the subject Honda were to the driver's side and front, respectively.

The reviewed photographic reproductions of the subject Honda indicated damage to the complete front structure along with deployment of the driver's side airbag. The reviewed photographic reproductions of the incident Chevrolet indicated damage to the driver's side truck bed.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Honda and geometric measurements of a 1992 Honda Civic revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Honda Civic would result in significant and visibly noticeable crush across the entirety of the subject vehicle's front structure, with a residual crush of 2.0 inches to the outer structures and a maximum of 5.0 inches at six inches outboardof the center to the drivers side. Therefore, the engineering analysis shows comparable would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The comparable structural crush to the front of the subject Honda indicates that the subject incident is consistent with a collision resulting in a Delta-V comparable to 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

However, because of a bumper mismatch, the bumpers did not make direct contact and the incurred crush was directed into the non-bumper areas of the Honda. An accepted methodology calls for reducing the deformation by 50% when override occurs when performing crush calculations or averaging the overall crush and bumper crush.[18]

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to 10 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the peak acceleration associated with a 10-mile-per-hour impact is

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11 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, NS, Smith, RA, Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Tumbas, N. and Smith, R., *Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View*, Society of Automotive Engineers, Warrendale, PA, Publication 880072, 1988.

6.0g.[19] By the laws of physics, the peak acceleration experienced by the subject Honda in which Ms. Baccay was seated was comparable to 6.0g.

The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average 3g associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which Ms. Baccay was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Baccay's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. Baccay was wearing the available three-point restraint system at the time of the subject incident. Ms. Baccay's principle direction of motion would be forward, relative to her vehicle. Additionally, according to a crash test with greater severity, a FMVSS 208 Test for a 1992 Honda Civic, the anthropomorphic test device (ATD) did not strike the interior of the test vehicle which is consistent with Ms. Baccay's testimony that she did not strike the interior of the vehicle. [22]

The laws of physics dictate that front contact to the subject Honda with the driver's side of the incident Chevrolet would have caused the subject Honda to decelerate. Based upon my review of motor vehicle crash tests, results cited in the scientific literature,[23,24] and the laws of physics, Ms. Baccay's body would have moved forward relative to the Honda's interior. The three-point restraint that Ms. Honda testified she was wearing would have locked when the vehicle accelerations exceeded 0.7g,[25] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Ms. Honda, as well as the passive muscle resistance of her arms would have acted in conjunction with her three-point restraint to limit body motion. Provided the

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19 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

20 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

22 Federal Motor Vehicle Safety Standard. (FMVSS). Report Number 208-CAL-92-13, 1992 Honda Civic. Washington, DC, U.S. Department of Transportation National Highway Traffic Safety Administration.

23 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

24 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

25 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

accelerations of the subject incident, and the supports described, the bodily response of Ms. Baccay would have been limited to within normal physiological limits.

Findings:

1. On August 27, 2008, Ms. Cayetana Baccay was the belted right front passenger of a 1992 Honda Civic that was contacted in the front.
2. The change in velocity was comparable to 10 miles-per-hour with peak accelerations comparable to 6.0g.
3. The acceleration experienced by Ms. Baccay was within the limits of human tolerance, the personal tolerance levels of Ms. Baccay and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Baccay was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

While the upper torso is constrained in this incident the head and cervical spine is unrestrained; which may result in a cervical sprain/strain type of injury.

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[26] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[27] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[28]

Thoracic and Lumbar Spine

According to an MRI of Ms. Baccay's lumbar spine dated December 14, 2011, there were findings consistent with L2-3, L3-4, L4-5 and L5-S1 mild endplate spondylitic changes with bulges. Additionally, according to other available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

In this type of collision, the motion of Ms. Baccay's thoracic and lumbar spine would have been well supported and constrained. Ms. Baccay's body would have moved forward relative to the Honda's interior. As described previously, Ms. Baccay testified that she was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[29] Therefore, Ms. Baccay's thoracic and lumbar spine motion would have been limited to only non-significant flexion with the potential for minimal lateral bending during the subject incident. As a result, the motion of Ms. Baccay's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[30] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[31] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts

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28 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

29 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

30 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

31 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

with an acceleration level of 12g.[32] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[33] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[34] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic injury. The subject incident had a peak acceleration comparable to 6.0g. Ms. Baccay's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of physiologic tolerance levels.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Baccay, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On August 27, 2008, Ms. Cayetana Baccay was the belted right front passenger of a 1992 Honda Civic that was contacted in the front.
2. The severity of the subject incident was consistent with a Delta-V comparable to 10 miles-per-hour with peak acceleration comparable to 6.0g for the subject 1992 Honda Civic in which Ms. Baccay was seated.
3. The acceleration experienced by Ms. Baccay was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupant's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.

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[32] Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

[33] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[34] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

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5. There is no causal link between the reported lumbar injuries of the occupant and this reported collision. Ms. Baccay experiences loading on a daily basis greater than that experienced in this incident. An injury mechanism for the claimed thoracic and lumbar injury was not present in the subject incident. There would be no motion of the thoracic and lumbar outside of the normal physiologic range of motion.

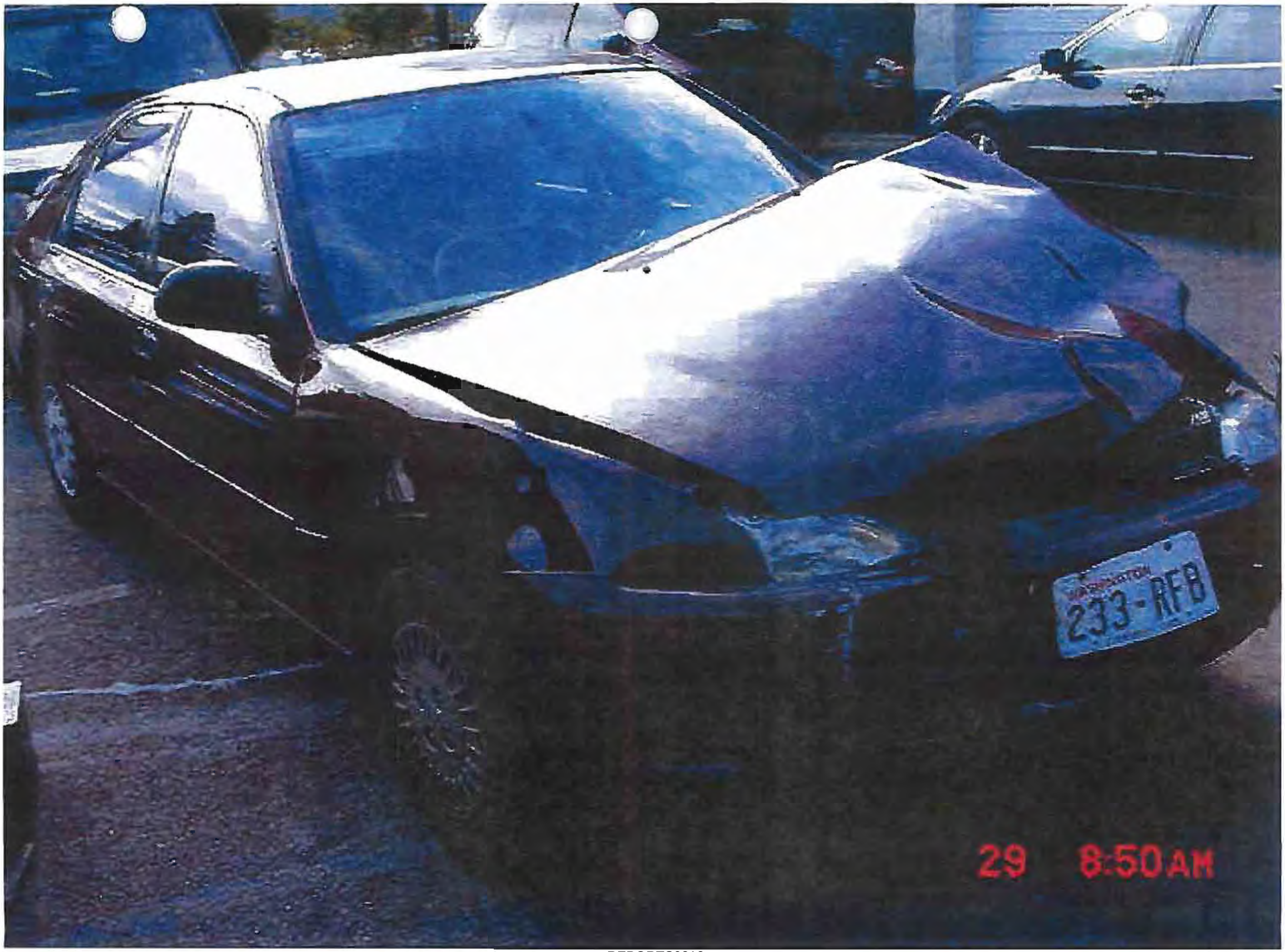
If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr


EXHIBIT 24
WIT:
DATE: 8-8-13
ELAINE RIPPEN, CCR
29 8:50AM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29 8:50AM

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EXHIBIT
PENGAD 800-631-6989
Probst 18
5-23-12 Am Y

February 22, 2012

Mark Wheeler, Esquire
900 Washington St, Suite 1020
Vancouver, WA 98666

Re: *LeBaron, Sandra v. Erin lee*
File No.: 00-331-006439
ARCCA Case No.: 3104-103

Dear Mr. Wheeler:

Thank you for the opportunity to participate in the above-referenced matter. ARCCA, Incorporated was previously retained to evaluate the subject incident in relation to the forces involved in the incident of Sandra LeBaron. This letter is meant to supplement my report of August 8, 2011. I would like to correct a typographical error in the 'Damage and Incident Severity' section of my report near the bottom of page 4.

The report issued on August 8, 2011 reads as follows:

"The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Toyota Camry, defined by the photographic reproductions, and **confirmed by the repair estimate**, was used to perform a damage threshold speed change analysis."

The bold section above should be changed to: **confirmed by my vehicle inspection**.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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August 8, 2011

John Adlard, Esquire
John F. Adlard, Attorney at Law
P.O. Box 3769
Portland, OR 97208

Re: *LeBaron, Sandra v. Erin lee*
File No.: 00-331-006439
ARCCA Case No.: 3104-103

Dear Mr. Adlard:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Sandra LeBaron. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on April 24, 2009, Ms. Sandra LeBaron was the restrained driver of a 2002 Toyota Camry traveling eastbound on State Route 4 (One Beach Highway) in Longview, Washington. Ms. Erin Lee was the restrained driver of a 2000 Toyota Camry traveling on State Route 4 directly behind the subject Toyota Camry. Ms. Darla Bernard was the restrained driver of a 2004 Dodge Stratus traveling on State Route 4 directly in front of the subject Toyota Camry. According to the available documents, the subject Toyota Camry and pushed into the incident Dodge Stratus. As a result, the front bumper of the incident Toyota contacted the rear of the subject Toyota and the front bumper of the subject Toyota contacted the rear of the incident Dodge. No airbags were deployed as a result of the impact, and no vehicles were towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Case No.: 209-8881
- Thirteen (13) color photographic reproductions of the subject vehicle 2002 Toyota Camry
- Seven (7) color photographic reproductions of the incident vehicle 2004 Dodge Stratus
- Sixty-three (63) color photographic reproductions of the incident vehicle 2000 Toyota Camry
- American Family Insurance repair estimate for the subject vehicle 2002 Toyota Camry [April 29, 2009]
- Fender Mender Body & Frame Repair preliminary estimate for the incident vehicle 2004 Dodge Stratus [April 28, 2009]
- American Family Insurance repair estimate for the incident vehicle 2004 Dodge Stratus [April 29, 2009]
- Fender Mender Body & Frame Repair preliminary Supplement 1 with Summary for the incident vehicle 2004 Dodge Stratus [May 13, 2009]
- American Family Insurance Supplement 1 for the incident vehicle 2004 Dodge Stratus [May 15, 2009]
- American Family Insurance First Notice of Loss, Claim No.: 00-331-006439
- Recorded Statement Transcript of Sandra LeBaron [April 27, 2009]
- Deposition Transcript of Sandra LeBaron [march 25, 2011]
- Medical Records pertaining to Sandra LeBaron
- Vehicle Inspection of the incident 2000 Toyota Camry by Brad Probst [July 22, 2011]

- VinLink data sheet for the subject 2002 Toyota Camry
- Expert AutoStats data sheets for a 2002 Toyota Camry
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2002 Toyota Camry
- VinLink data sheet for the incident 2004 Dodge Stratus
- Expert AutoStats data sheets for a 2004 Dodge Stratus
- Expert AutoStats data sheets for a 2001 Dodge Stratus
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2001 Dodge Stratus
- VinLink data sheet for the incident 2000 Toyota Camry
- Expert AutoStats data sheets for a 2000 Toyota Camry
- Expert AutoStats data sheets for a 1997 Toyota Camry
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1997 Toyota Camry

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. LeBaron claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. LeBaron was occupying;
3. Determine Ms. LeBaron's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. LeBaron's response to the subject incident.
5. Evaluate Ms. LeBaron's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. LeBaron has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Broad based posterior disc protrusion at the C4-5 level
  - Moderate disc space narrowing and degenerative disc bulge at the C5-6 level
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota Camry, incident Toyota Camry and incident Dodge Stratus in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear and subsequent frontal impact between the subject Toyota and the incident Toyota and Dodge, where the primary points of impact to the subject Toyota were to the front and rear, the front of the incident Toyota and the rear of the incident Dodge.

The damage estimate of the subject Toyota indicated damage primarily to the front bumper cover, left and right floor reinforcement, left and right quarter panel, left and right quarter panel extension, rear deck lid, rear body panel, and rear bumper assembly, which is consistent with the reviewed photographic reproductions. I inspected the incident Toyota and the damage was primarily to the front bumper cover, energy absorber and grille. The damage estimate of the incident Dodge indicated damage primarily to the rear bumper cover, reinforcement bar and energy absorber, which is consistent with the reviewed photographic reproductions

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Toyota can be used to resolve the loads sustained by the subject Toyota. That is, the forces sustained by the incident Toyota are equal and opposite to those of the subject Toyota.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Toyota Camry, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 1997 Toyota Camry, essentially the same vehicle as a 2000 Toyota Camry. In a five mile-per-hour frontal impact into a flat barrier the test Toyota sustained damage primarily to the bumper reinforcement

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

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and battery bracket. The primary damage to the incident Toyota Camry due to the subject incident was to the front bumper cover, energy absorber and grille. Thus, because the test Toyota in the IIHS frontal impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Camry, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[12] The IIHS tested a 2002 Toyota Camry in a five mile-per-hour rear and frontal impact into a flat barrier. The test Toyota in the rear impact sustained damage primarily to the rear bumper cover, bumper reinforcement and rear body panel. The primary damage to the subject Toyota Camry due to the rear impact of the subject incident was to the left and right floor reinforcement, left and right quarter panel, left and right quarter panel extension, rear deck lid, rear body panel, and rear bumper assembly. The test Toyota in the frontal impact sustained damage primarily to the front bumper, absorber and reinforcement. The primary damage to the subject Toyota Camry due to the frontal impact of the subject incident was to the front bumper cover. Thus, because the test Toyota in the IIHS rear and frontal impact tests sustained comparable damage, the severity of the IIHS impacts are comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Further analyzing the subsequent frontal impact, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Dodge Stratus, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested a 2001 Dodge Stratus, essentially the same vehicle as a 2004 Dodge Stratus. In a five mile-per-hour rear impact into a flat barrier the test Dodge sustained damage primarily to the rear bumper reinforcement and left and right rear bumper mounting brackets. The primary damage to the incident Dodge Stratus due to the subject incident was to the rear bumper cover, reinforcement bar and energy absorber. Thus, because the test Dodge in the IIHS rear impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, the conservation of momentum and my experience indicates a rear and subsequent frontal impact, each resulting in a Delta-V comparable to 5 miles-per-hour for the subject Toyota Camry. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[14] By the laws of

[12] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[13] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[14] Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

physics, the average acceleration experienced by the subject Toyota in which Ms. LeBaron was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. LeBaron experiences 1g of loading while in a sedentary state. Therefore, Ms. LeBaron experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. LeBaron in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. LeBaron testified that prior to the subject incident she was capable of playing with her grandkids, decorating the house, moving furniture, planting flowers, watering flowers and maintaining her yard. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[15] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[16]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota in which Ms. LeBaron was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. LeBaron's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. LeBaron was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. LeBaron's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. LeBaron testified that she had reached into the passenger seat at the time of the subject incident.

The laws of physics dictate that when the incident Toyota contacted the rear of the subject Toyota, had there been enough energy transferred to initiate motion, the Toyota would have been pushed forward causing Ms. LeBaron's seat to move forward relative to her body, which would result in Ms. LeBaron moving rearward relative to the interior of the subject vehicle. This interaction between Ms. LeBaron and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. Based upon my review of motor vehicle crash tests, results cited in the scientific literature,[17,18]

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15 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

16 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

17 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

and the laws of physics, due to the subsequent frontal impact had the forces generated during this interaction been sufficient to overcome the muscle reaction forces of Ms. LeBaron, her body would have moved forward relative to the Toyota's interior. The three-point restraint that Ms. LeBaron testified she was wearing would have locked when the vehicle accelerations exceeded 0.7g,[19] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Ms. LeBaron, as well as the passive muscle resistance of her arms would have acted in conjunction with her three-point restraint to limit body motion. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. LeBaron would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 24, 2009, Ms. Sandra LeBaron was the belted driver of a 2002 Toyota Camry that was contacted in the rear at low speed.
2. The changes in velocity were comparable to 5 miles-per-hour with average accelerations comparable to 1.5g.
3. The acceleration experienced by Ms. LeBaron was within the limits of human tolerance, the personal tolerance levels of Ms. LeBaron and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. LeBaron was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[20,21]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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18 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

19 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

20 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

21 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[22]

Cervical Spine

According to an MRI of Ms. LeBaron's cervical spine dated January 27, 2010, there were findings consistent with a broad based posterior disc protrusion at the C4-5 level which is associated with a dorsal annular tear. The cervical MRI also found moderate disc space narrowing and degenerative disc bulge at the C5-6 level. Additionally other medical records indicate there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota would be pushed forward and Ms. LeBaron would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat. The available documents indicate that Ms. LeBaron's head contacted the headrest. Due to the frontal impact, had the forces generated been sufficient to overcome Ms. LeBaron's muscle reaction forces, her body would have moved forward relative to the Toyota's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Toyota. Ms. LeBaron's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[23] A kinematic analysis of Ms. LeBaron's response to the subject incident demonstrated that her

22 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

23 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

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overall head motion would have been relatively minimal.[24,25] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.

Examination of an exemplar 2003 Toyota Camry, essentially the same vehicle as a 2002 Toyota Camry, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.0 inches in the "full down" position and 33.75 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. LeBaron's age (55 years), height (67-68 inches) and weight (195-205 lbs), Ms. LeBaron has a normal seated height of 33.8-34.2 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. LeBaron and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. LeBaron in the subject incident. The subject incident had an average

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24 Araszewski, M., Roenitz, E., and Toor, A., (1999). Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

25 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004). Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

26 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

27 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

29 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

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acceleration of 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. LeBaron would not have been exposed to any loading or motion outside of her personal tolerance levels.

Furthermore, numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[32] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[33] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine injury potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical injury are greater that that associated with the subject incident.[34,35] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[36] None of the participants reported any chronic cervical injuries. Arbogast et al.[37] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[38] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

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30 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

31 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

33 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

34 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

35 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

36 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

37 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[39,40] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. LeBaron cannot be made.

Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. Due to the subsequent frontal impact, provided sufficient energy to overcome Ms. LeBaron's muscle reaction forces, her body would have moved forward relative to the Toyota's interior. As described previously, Ms. LeBaron testified that she was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[41] Therefore, Ms. LeBaron's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

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39 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

40 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

41 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[42] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[43] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[44] The subject incident had an average acceleration comparable to 1.5g. Ms. LeBaron's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[45,46,47,48,49] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[50] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[51]

Additionally, several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[52] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[53] investigated frontal

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42 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

43 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

44 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

45 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

46 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

47 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

48 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

49 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

50 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

51 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

52 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

53 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[54] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[55] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[56] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic injury. The subject incident had an average acceleration comparable to 1.5g. Ms. LeBaron's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. LeBaron, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 24, 2009, Ms. Sandra LeBaron was the belted driver of a 2002 Toyota Camry that was contacted in the rear at low speed.
2. The severity of each impact during the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with an average acceleration comparable to 1.5g for the subject 2002 Toyota Camry in which Ms. LeBaron was seated.
3. The acceleration experienced by Ms. LeBaron was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. During the rear impact, the forces applied to the subject vehicle during the subject incident would tend to move the Ms. LeBaron's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

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54 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

55 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

56 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

5. During the subsequent frontal impact, the forces applied to the subject vehicle during the subject incident would tend to move the Ms. LeBaron's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.

6. There is no injury mechanism present in the subject incident to account for Ms. LeBaron's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.

7. There is no injury mechanism present in the subject incident to account for Ms. LeBaron's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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March 7, 2012

Melinda Wieder, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Stokesberry, Patricia & Leah v. Felila & Marvin Maaele and Fogavai Tualatamalelagi*
Claim No.: 3406 8789 3017
ARCCA Case No.: 3271-140

Dear Ms. Wieder:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Patricia Stokesberry and Leah Stokesberry. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on April 26, 2009, Ms. Patricia Stokesberry was the restrained driver of a 1993 Honda Accord traveling on C Street SW in Auburn, Washington. Ms. Leah Stokesberry was the restrained right front passenger in the 1993 Honda Accord. Ms. Felila Maaele was the driver of a 2006 Kia Spectra traveling on C Street SW directly behind the Honda. According to the available documents, the Honda stopped for a stop light and the Kia failed to stop in time. As a result, the front bumper of the incident Kia contacted the rear bumper of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eighteen (18) color photographic reproductions of the subject 1993 Honda Accord
- Twelve (12) color photographic reproductions of the incident 2006 Kia Spectra
- Exhibition Automotive, Inc. repair estimate for the subject 1993 Honda Accord [May 13, 2009]
- Kirmac Collision Services – Auburn Preliminary Estimate for the subject 1993 Honda Accord [April 30, 2009]
- First National Insurance Company of America Repair Estimate for the incident 2006 Kia Spectra [May 19, 2009]
- Medical Records pertaining to Patricia Stokesberry
- Medical Records pertaining to Leah Stokesberry
- VinLink data sheet for the subject 1993 Honda Accord
- Expert AutoStats data sheets for a 1993 Honda Accord
- VinLink data sheet for the incident 2006 Kia Spectra
- Expert AutoStats data sheets for a 2006 Kia Spectra
- Expert AutoStats data sheets for a 2008 Kia Spectra
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2008 Kia Spectra

ARCCA

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that the occupants claim were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle the occupants were occupying;
3. Determine the occupants' kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during the occupants' response to the subject incident;
5. Evaluate the occupants' personal tolerance in the context of their pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and their reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Patricia Stokesberry has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
    - Small central disc extrusion at C4-5
    - Mild diffused disc protrusion with focal extrusion at C5-6
    - Disc protrusion at C6-7
- Thoracic and Lumbar Spine
    - Sprain/strain

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

According to the available documents, Ms. Leah Stokesberry has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic, Lumbar and Lumbosacral Spine
    - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Accord and incident Kia Spectra in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Kia, where the primary points of impact to the incident Kia and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda Accord indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions. The damage estimate of the incident Kia Spectra indicated damage primarily to the front bumper cover and right headlamp assembly; which is consistent with the reviewed photographic reproductions.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Kia can be used to resolve the loads sustained by the subject Honda. That is, the forces sustained by the incident Honda are equal and opposite to those of the subject Kia.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Kia Spectra, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2008 Kia Spectra, essentially the same vehicle as a 2006 Kia Spectra. In a 6.2 mile-per-hour frontal impact into a flat barrier the test Kia sustained damage to the front bumper cover, front bumper absorber, grille assembly, left and right headlamp assembly, hood, hood latch, radiator support panel assembly, radiator panel baffle, AC condenser, and left fender. The primary damage to the incident Kia was to the front bumper cover and right headlamp assembly. Thus, because the test Kia in the IIHS frontal impact test sustained greater damage, the severity of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at the test speed of 6.2 miles-per-hour. Conservation of momentum indicates an incident speed of 5.8 miles-per-hour for the subject Honda.

Review of the vehicle damage, incident data, published literature, engineering analyses, the conservation of momentum and my experience indicates an incident resulting in a Delta-V of 5.8 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5.8

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

mile-per-hour impact is 1.8g.[12] By the laws of physics, the average acceleration experienced by the subject Honda in which Ms. Patricia Stokesberry and Ms. Leah Stokesberry were seated was a nominal 1.8g.

The acceleration experienced due to gravity is 1g. This means that both Ms. Patricia Stokesberry and Ms. Leah Stokesberry experience 1g of loading while in a sedentary state. Therefore, Ms. Patricia Stokesberry and Ms. Leah Stokesberry experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by either occupant in their daily life would have increased the loading to their body beyond the sedentary 1g. According to the available documents, Ms. Patricia Stokesberry was capable of cooking, cleaning, exercising and working her job at Lowes prior to the subject incident. Regarding Ms. Leah Stokesberry, according to the available documents, she was capable of running, playing basketball, exercising and working her job at Sears prior to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which the occupants were seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for the occupants' claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, the occupants were wearing the available seat belt system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, the occupants' principle direction of motion would be rearward, relative to the subject vehicle. Additionally, the available documents indicate the occupants were in a proper seated position and were unaware of the impending impact.

The laws of physics dictate that when the incident Kia contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing the occupants' seats to move forward relative to their bodies, which would result in the occupants moving rearward relative to the interior of the subject vehicle. This

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12 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

13 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

interaction between the occupants and the subject vehicle's interior would cause each occupant's body to load into their respective seatback structure. Specifically, each occupant's torso and pelvis would settle back into their respective seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of either occupant's body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of the occupants would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 26, 2009, Ms. Patricia Stokesberry was the belted driver of a 1993 Honda Accord that was contacted in the rear at low speed. Ms. Leah Stokesberry was the belted right front passenger in the 1993 Honda Accord.
2. The change in velocity was 5.8 miles-per-hour with average accelerations of a nominal 1.8g.
3. The acceleration experienced by both occupants was within the limits of human tolerance and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to both occupants was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link the occupant's reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection **5**(1): 55-66.

18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[20]

Cervical Spine
According to an MRI pertaining to Ms. Patricia Stokesberry's cervical spine dated May 18, 2009, there were findings consistent with a small central disc extrusion at C4-5, marked narrowing and degenerative disc disease at C5-6 along with a mild diffuse protrusion with focal extrusion along the right lateral recess bordered by osteophyte formations. The MRI report also reported findings consistent with a disc protrusion and osteophyte formations at the C6-7 level. Additionally, the medical records report a cervical sprain/strain.

According to the available document for Ms. Leah Stokesberry, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and each occupant would have moved rearward relative to the vehicle, until their motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1993 Honda Accord showed that the nominal height of the front seats with an unoccupied, uncompressed seat is 30.5 inches in the "full down" position and 32.0 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Patricia Stokesberry's age

[20] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

(47 years), height (62 inches) and weight (137 lbs), she has a normal seated height of 31.7 inches. Based on an anthropometric regression of Ms. Leah Stokesberry's age (20 years), height (67 inches) and weight (147 lbs), she has a normal seated height of 34.0 inches. Thus, each seat is tall enough to have prevented hyperextension of both occupants and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[21] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[22] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[23] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[24] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by the occupants in the subject incident. The subject incident had an average acceleration significantly below 1.8g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[25,26] The occupants would not have been exposed to any loading or motion outside of their personal tolerance levels.

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21 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

22 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

23 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* **6**:366-375.

24 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* **29**:979-987.

25 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* **42**: 25-30.

26 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[27,28] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause acute disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Patricia Stokesberry and Ms. Leah Stokesberry cannot be made.

Thoracic, Lumbar and Lumbosacral Spine
According to the available documents, both occupants had findings consistent with a thoracic and lumbar sprain/strain. Additionally, Ms. Leah Stokesberry had findings consistent with a lumbosacral sprain/strain.

There is no reason to assume that the claimed thoracic, lumbar and lumbosacral spine injuries are causally related to the subject incident. In a rear impact the pelvis and thoracic and lumbar spine of an occupant are well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic and lumbar spine and pelvis. Thus, the seatback would limit the range of motion to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the upper body. The seatback would not allow for hyperextension of the occupants' thoracic and lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless one portion of the spine is supported with another portion unsupported. As a result of the subject incident, the occupant's torso and pelvis would settle back into the seatback structures. The low accelerations resulting from this collision would have caused little, or no, forward rebound of the occupant's body away from the seat back.[29,30,31] Any rebound would have been within the range of protection afforded by the available restraint system and significant loading to the occupants' thoracic and lumbar spine would not be expected.

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27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

29 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

30 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

31 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection **5**(1): 55-66.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[32] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[33] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[34] The subject incident had an average acceleration significantly below 1.8g. The occupants' thoracic, lumbar, and lumbosacral spines would not have been exposed to any loading or motion outside of the range of their personal tolerance levels.[35,36,37,38,39] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[40] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[41]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar and lumbosacral spine. The forces created by the incident were well within the limits of human tolerance for thoracic, lumbar and lumbosacral strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and the thoracic,

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32 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

33 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

34 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

35 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

36 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

37 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* **7**(3): 184-191.

38 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* **16**: 549-559.

39 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

40 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* **42**: 410-415.

41 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* **29**(20): 2319-2329.

lumbar and lumbosacral spine injuries claimed by Ms. Patricia Stokesberry and Ms. Leah Stokesberry cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 26, 2009, Ms. Patricia Stokesberry was the belted driver of a 1993 Honda Accord that was contacted in the rear at low speed. Ms. Leah Stokesberry was the belted right front passenger in the 1993 Honda Accord.
2. The severity of the subject incident was consistent with a Delta-V of 5.8 miles-per-hour with an average acceleration of 1.8g for the subject 1993 Honda Accord in which Ms. Patricia Stokesberry and Ms. Leah Stokesberry were seated.
3. The acceleration experienced by both occupants was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupants' bodies back toward their respective seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for the occupants' claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for the occupants' claimed thoracic, lumbar and lumbosacral spine injuries. As such, a causal relationship between the subject incident and the thoracic, lumbar and lumbosacral injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

ARCCA, INCORPORATED
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SEATTLE, WA 98105
PHONE 877-942-7222 FAX 206-547-0759
www.arcca.com

EC

EXHIBIT
Probst 19
5-23-17

March 16, 2012

LOO ... Seattle ...

MAR 26 2012

Claim/Defense #

Retain ... NO

Eric Chavez, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Zenner, Patricia v. Victor Grabar*
Claim No.: 978162614008
ARCCA Case No.: 3271-147

Dear Mr. Chavez:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Patricia Zenner. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on November 12, 2009, Ms. Patricia Zenner was the restrained driver of a 2010 Ford Focus traveling northbound on Bridgeport Way in Tacoma, Washington. Mr. Victor Grabar was the driver of a 2005 Buick Park Avenue traveling on Bridgeport Way directly behind the Ford. According to the available documents, the Ford was stopped for traffic and was struck from behind by the incident Buick. As a result, the front bumper of the incident Buick contacted the rear of the subject Ford. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- One (1) color photographic reproductions of the subject 2010 Ford Focus
- Eleven (11) color photographic reproductions of the incident 2005 Buick Park Avenue
- Maaco Collision Repair & Auto Painting repair estimate for the subject 2010 Ford Focus [January 22, 2010]
- Safeco Insurance Company of Illinois Supplement of Record 1 with Summary for the incident 2005 Buick Park Avenue [November 24, 2009]
- Gilchrist Collision Center Preliminary Supplement 1 with Summary for the incident 2005 Buick Park Avenue [December 3, 2009]
- Complaint for Damages, *Patricia Zenner vs. Victor Grabar and Jane Doe Grabar* [October 24, 2011]
- Deposition Transcript of Patricia Lund [February 2, 2012]
- Medical Records pertaining to Patricia Zenner
- VinLink data sheet for the subject 2010 Ford Focus
- Expert AutoStats data sheets for a 2010 Ford Focus
- Expert AutoStats data sheets for a 2000 Ford Focus
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2000 Ford Focus
- VinLink data sheet for the incident 2005 Buick Park Avenue
- Expert AutoStats data sheets for a 2005 Buick Park Avenue
- Expert AutoStats data sheets for a 1999 Buick Park Avenue
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1999 Buick Park Avenue

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Zenner claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Zenner was occupying;
3. Determine Ms. Zenner's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Zenner's response to the subject incident.
5. Evaluate Ms. Zenner's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Zenner has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
- Bilateral Shoulders
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Ford Focus and incident Buick Park Avenue in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Ford and the Buick, where the primary points of impact to the incident Buick and the subject Ford were to the front and rear, respectively.

The damage estimate of the subject Ford Focus indicated damage primarily to the rear bumper cover and rear impact bar; which is consistent with the reviewed photographic reproduction (Figure 1). The damage estimate of the incident Buick Park Avenue indicated damage primarily to the front bumper cover, left side molding, hood, grille, latch, striker, latch support and AC condenser; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproduction of the subject 2010 Ford Focus

Figure 2: Reproduction of the incident 2005 Buick Park Avenue

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the loads sustained by the incident Buick can be used to resolve the loads sustained by the subject Ford. That is, the loads sustained by the incident Buick are equal and opposite to those of the subject Ford.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Buick Park Avenue, defined by the photographic reproductions, and confirmed by the repair

estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 1999 Buick Park Avenue, essentially the same vehicle as a 2005 Buick Park Avenue. In a five mile-per-hour full frontal impact into a flat barrier the test Buick sustained damage primarily to the left and right front bumper mounting brackets and the left and right frame sidemembers. The incident Buick underrode the Ford and sustained damage primarily to the front bumper cover, left side molding, hood, grille, latch, striker, latch support and AC condenser. Thus, because the test Buick in the IIHS frontal impact test sustained more damage to structural components, the severity of the IIHS impact is greater than the severity of the subject incident and places the subject incident speed at the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with the IIHS rear impact test for a Ford Focus.

Review of the vehicle damage, incident data, published literature, engineering analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V of less than 7.0 miles-per-hour for the subject Ford Focus. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 7.0 mile-per-hour impact is 2.1g.[12] By the laws of physics, the average acceleration experienced by the subject Ford in which Ms. Zenner was seated was less than 2.1g.

The acceleration experienced due to gravity is 1g. This means that Ms. Zenner experiences 1g of loading while in a sedentary state. Therefore, Ms. Zenner experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Zenner in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Zenner testified that prior to the subject incident she performed cardio exercise every day, worked in her yard, gardened and vacuumed. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[14]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Ford in which Ms. Zenner was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Zenner's claimed injuries in the subject incident.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

13 Mow, V. C. and W. C. Hayes (1991). <u>Basic Orthopaedic Biomechanics</u>. New York, Raven Press.

14 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

Kinematic Analysis:

Ms. Zenner testified that she was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Zenner's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. Zenner testified that her body went backward then forward and was caught by the seatbelt.

The laws of physics dictate that when the incident Buick contacted the rear of the subject Ford, had there been enough energy transferred to initiate motion, the Ford would have been pushed forward causing Ms. Zenner's seat to move forward relative to her body, which would result in Ms. Zenner moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Zenner and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Zenner would have been limited to well within the range of normal physiological limits.

Findings:

1. On November 12, 2009, Ms. Patricia Zenner was the belted driver of a 2010 Ford Focus that was contacted in the rear at low speed by a 2005 Buick Park Avenue.
2. The change in velocity was less than 7.0 miles-per-hour with average accelerations less than 2.1g.
3. The acceleration experienced by Ms. Zenner was within the limits of human tolerance, the personal tolerance levels of Ms. Zenner and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Zenner was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range

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[15] Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[16] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[17] Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[18,19]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford Focus would be pushed forward and Ms. Zenner would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2000 Ford Focus, essentially the same vehicle as a 2010 Ford Focus, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30.5 inches in the "full-down" position and 33.0 inches in the "full-up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Zenner's age (57 years), height (64 inches) and weight (184 lbs), Ms. Zenner has a normal seated height of 32.5 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Zenner and one would not expect to see any injuries greater than transient

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18 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[20] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[21] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[22] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[23] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Zenner in the subject incident. The subject incident had an average acceleration less than 2.1g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[24,25] Ms. Zenner would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[26,27] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

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20 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

21 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

22 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

23 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

24 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

25 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

26 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

ARCCA

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Zenner cannot be made.

Bilateral Shoulders, Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a bilateral shoulder, thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

Additionally, there is no reason to assume that the claimed bilateral shoulder injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford would be pushed forward and Ms. Zenner would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. Furthermore, as previously stated Ms. Zenner's body would have moved rearward and the interaction with the seatback and her body would have minimized her motion. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Zenner's body away from the seatback.[28] Any rebound that may have occurred would have been limited by the available restraint system. Any load acting on the shoulders due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the injury mechanisms necessary to cause injury to either of her shoulders.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[29] The only symptoms reported in the study were minor neck pains for two volunteers

28 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

29 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." <u>Accident Reconstruction Journal</u>.

which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[30] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[31] The subject incident had an average acceleration less than 2.1g. Ms. Zenner's thoracic and lumbar spine and shoulders would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[32,33,34,35,36] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[37] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[38]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Zenner, a causal link between the subject incident and claimed shoulder, lumbar spine and thoracic spine injuries cannot be made.

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30 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

31 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

32 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

33 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

34 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

35 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

36 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

37 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

38 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On November 12, 2009, Ms. Patricia Zenner was the belted driver of a 2010 Ford Focus that was contacted in the rear at low speed by a 2005 Buick Park Avenue.
2. The severity of the subject incident was consistent with a Delta-V less than 7.0 miles-per-hour with an average acceleration less than 2.1g for the subject 2010 Ford Focus in which Ms. Zenner was seated.
3. The acceleration experienced by Ms. Zenner was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Zenner's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Zenner's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Zenner's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.
7. There is no injury mechanism present in the subject incident to account for Ms. Zenner's claimed bilateral shoulder injuries. As such, a causal relationship between the subject incident and the bilateral shoulder injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
Probst 20
5-23-17

March 26, 2012

Kaci Callahan, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Nguyen, Thu v. David, Dalen & Evelyn Guieb*
Claim No.: 695893344008
ARCCA Case No.: 3271-149

Dear Ms. Callahan:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Thu Nguyen. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I - Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering. 2: 55-81.

5 King, A.L. (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering. 3: 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On September 16, 2010, Ms. Thu Nguyen was the restrained driver of a 1999 Honda Accord traveling on a roadway in the Beacon Hill area of Seattle, Washington. Mr. Dalen Guieb was the driver of a 1999 Jeep Grand Cherokee traveling on the roadway directly behind the Honda. According to the available documents, the Honda was stopped at a red traffic signal and the incident Jeep was unable to stop in time. As a result, the front bumper of the incident Jeep contacted the rear of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 1999 Honda Accord
- Twelve (12) color photographic reproductions of the incident 1999 Jeep Grand Cherokee
- Exhibition Automotive, Inc. repair estimate for the subject 1999 Honda Accord [September 17, 2010]
- SIU Recorded Statement Summary Report of Thu Xuan Nguyen [September 29, 2010]
- SIU Recorded Statement Summary Report of Dalen Guieb [October 4, 2010]
- Medical records pertaining to Thu Nguyen
- VinLink data sheet for the subject 1999 Honda Accord
- Expert AutoStats data sheets for a 1999 Honda Accord
- Expert AutoStats data sheets for a 1998 Honda Accord
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1998 Honda Accord
- Expert AutoStats data sheets for a 1999 Jeep Grand Cherokee

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

[7] Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury. (SAE 940568). Warrendale, PA, Society of Automotive Engineers

1. Identify the injuries that Ms. Nguyen claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Nguyen was occupying;
3. Determine Ms. Nguyen's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Nguyen's response to the subject incident.
5. Evaluate Ms. Nguyen's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Nguyen has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Accord and incident Jeep Grand Cherokee in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Jeep, where the primary points of impact to the incident Jeep and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda Accord indicated damage primarily to the rear bumper cover and trunk lid; which is consistent with the reviewed photographic reproductions (Figure 1). The reviewed photographic reproductions of the incident Jeep Grand Cherokee do not depict any visible damage (Figure 2).

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8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

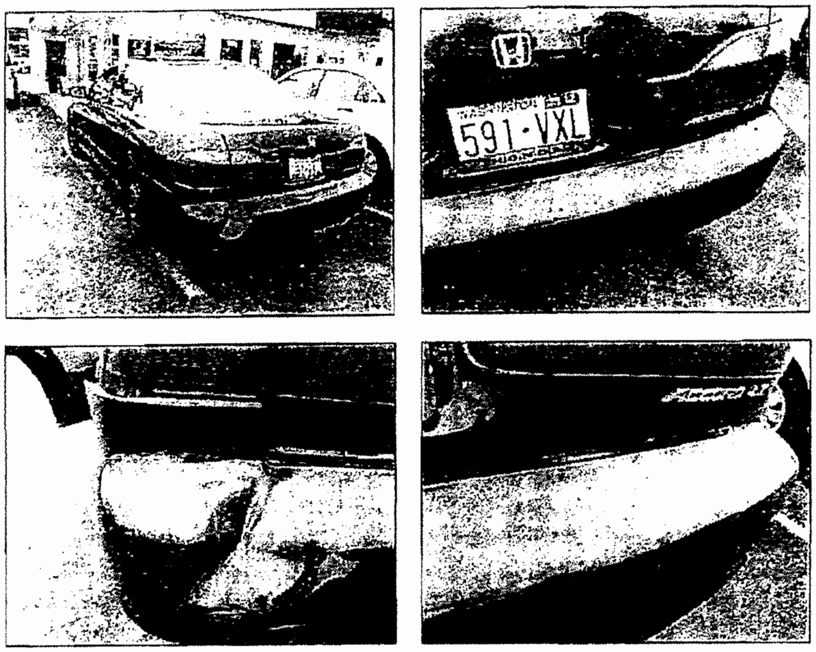

Figure 1: Reproductions of photographs of the subject 1999 Honda Accord

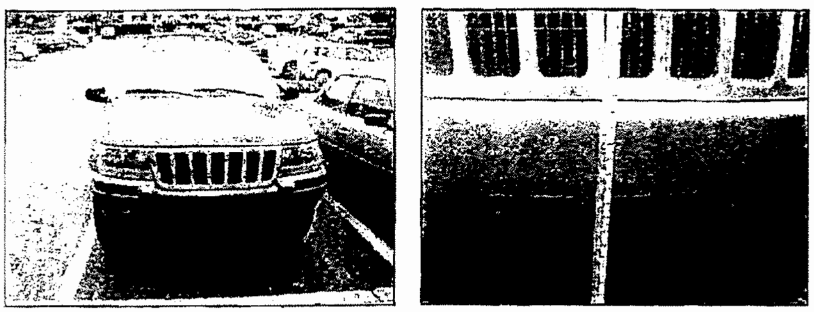

Figure 2: Reproductions of photographs of the incident 1999 Jeep Grand Cherokee

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Accord, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 1998 Honda Accord, essentially the same vehicle as a 1999 Honda Accord, in a five mile-per-hour rear impact into a flat barrier. The test Honda sustained damage to the rear bumper cover, rear bumper reinforcement, rear bumper absorber, rear bumper absorber insert and the rear body panel assembly. The primary damage to the subject Honda was to the rear bumper cover and trunk lid. Thus, because the test Honda in the IIHS rear impact test sustained more damage, the severity of the IIHS impact is greater compared to the severity of the subject incident, and places the subject incident speed at the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1999 Honda Accord and an IIHS low-speed crash test for a 1999 Jeep Grand Cherokee.[12,13,14,15,16,17,18]

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Honda Accord. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[19] By the laws of physics, the average acceleration experienced by the subject Honda in which Ms. Nguyen was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Nguyen experiences 1g of loading while in a sedentary state. Therefore, Ms. Nguyen experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Nguyen in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, prior to the subject incident Ms. Nguyen assisted the elderly with feeding, walking and washing clothes for a few hours each day. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers
12 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
16 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
17 Tumbas, NS, Smith, RA. Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
18 Insurance Institute for Highway Safety Low-Speed Crash Test Report (1999). Jeep Grand Cherokee, Arlington, VA. Insurance Institute for Highway Safety.
19 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA, Society of Automotive Engineers.

body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crush severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which Ms. Nguyen was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Nguyen's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Nguyen was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Nguyen's principle direction of motion would be rearward, relative to her vehicle. Additionally, the available documents indicate Ms. Nguyen was unaware of the impending impact and it caused her head to move forward then backward. This is contrary to the actual motions caused by the subject incident. The laws of physics dictate that when the incident Jeep contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing Ms. Nguyen's seat to move forward relative to her body, which would result in Ms. Nguyen moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Nguyen and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[22,23,24] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Nguyen would have been limited to well within the range of normal physiological limits.

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20 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M., (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

22 Szczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

23 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209. Mercedes-Benz of North America, Inc., December 7, 1989.

24 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Prevention 5(1): 55-66.

ARCCA

Findings:

1. On September 16, 2010, Ms. Thu Nguyen was the belted driver of a 1999 Honda Accord that was contacted in the rear at low speed by a 1999 Jeep Grand Cherokee.
2. The change in velocity was less than 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Ms. Nguyen was within the limits of human tolerance, the personal tolerance levels of Ms. Nguyen and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Nguyen was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, there were findings consistent with a cervical sprain/strain.

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[25] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[26] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

There is no reason to assume that the claimed cervical injury is causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and Ms. Nguyen would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1999 Honda Accord showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30.5 inches in the "full down" position and 32.5 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Nguyen's age (37 years), height (60 inches) and weight (108 lbs), Ms. Nguyen has a normal seated height of 30.9 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Nguyen and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Nguyen in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during

27 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

28 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

30 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Ms. Nguyen would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported acute cervical spine injury of Ms. Nguyen cannot be made.

Thoracic and Lumbar Spine

According to the available documents, there were findings consistent with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms were created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic or lumbar spine damage is created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph

31 Ng, T.P., Bussone, W.R., Duma, S.M. '2006' The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation* 42: 25-30.

32 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

34 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 1.5g. Ms. Nguyen's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Nguyen, a causal link between the subject incident and claimed acute injuries cannot be made.

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35 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal. .

36 Szabo, T. J., Welcher, J. B., et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA. Society of Automotive Engineers.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

38 Gushue, D., B. Probst, et al. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006. Seattle, WA, ASSE.

39 Nordin M. and Frankel V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger. Philadelphia, London.

40 Adams, M.A., Hutton, W.C. (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* 7(3): 184-191.

41 Schibye, B., Sogaard, K. et al. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

42 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts. (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

43 Ng, T.P., Bussone, W.R., Duma, S.M., (2006). Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

44 Kavcic, N., Grenier, S., McGill, S. (2004). Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On September 16, 2010, Ms. Thu Nguyen was the belted driver of a 1999 Honda Accord that was contacted in the rear at low speed by a 1999 Jeep Grand Cherokee.
2. The severity of the subject incident was consistent with a Delta-V less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 1999 Honda Accord in which Ms. Nguyen was seated.
3. The acceleration experienced by Ms. Nguyen was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Nguyen's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no injury mechanism present in the subject incident to account for Ms. Nguyen's claimed cervical injury. As such, a causal relationship between the subject incident and the cervical injury cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Nguyen's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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May 21, 2012

Judy Heit, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re: Torres-Mendoza, Guadalupe v. Oscar & Lorraine Leonard
Claim No.: 742281454039
ARCCA Case No.: 3271-151

Dear Ms. Heit:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Guadalupe Torres-Mendoza. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on January 15, 2011, Ms. Guadalupe Torres-Mendoza was the restrained driver of a 2005 Honda Civic traveling northbound on M Street SE in Auburn, Washington. Mr. Oscar Leonard was the restrained driver of a 1999 Chevrolet Lumina traveling westbound exiting a parking lot at 702 M Street SE. According to the available documents, the incident Chevrolet pulled in front of the subject Honda causing contact between the vehicles. As a result, the left front of the subject Honda contacted the left side of the incident Chevrolet. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Case No. 11-00596
- Two (2) color photographic reproductions of the subject 2005 Honda Civic
- Four (4) color photographic reproductions of the incident 1999 Chevrolet Lumina
- Gerber Collision & Glass – Renton repair estimate for the subject 2005 Honda Civic [January 19, 2011]
- Gerber Collision & Glass – Renton Supplement of Record for the subject 2005 Honda Civic [February 17, 2011]
- Safeco Insurance Company of America repair estimate for the incident 1999 Chevrolet Lumina [January 25, 2011]
- Recorded Statement Transcript of Oscar Leonard [January 19, 2011]
- Recorded Statement Transcript of Guadalupe Torres [January 21, 2011]
- Deposition Transcript of Guadalupe Torres [April 25, 2012]
- Medical Records pertaining to Guadalupe Torres-Mendoza
- VinLink data sheet for the subject 2005 Honda Civic
- Expert AutoStats data sheets for a 2005 Honda Civic
- Expert AutoStats data sheets for a 2001 Honda Civic
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2001 Honda Civic
- VinLink data sheet for the incident 1999 Chevrolet Lumina
- Expert AutoStats data sheets for a 1999 Chevrolet Lumina

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Torres-Mendoza claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Torres-Mendoza was occupying;
3. Determine Ms. Torres-Mendoza's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Torres-Mendoza's response to the subject incident;
5. Evaluate Ms. Torres-Mendoza's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Torres-Mendoza has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M. (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F. (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Civic and incident Chevrolet Lumina in association with accepted engineering methodologies. According to the available documents, the subject incident was a frontal impact between the Honda and the Chevrolet, where the primary points of impact to the incident Chevrolet and the subject Honda were to the left side and left front, respectively.

The damage estimate of the subject Honda Civic indicated damage primarily to the left lens and housing, impact bar, left stiffener, bumper cover, front retainers, hood, left fender, left side support, left side panel, upper tie bar, and required a frame pull; which is consistent with the reviewed photographic reproductions (Figure 1). The damage estimate of the incident Chevrolet Lumina indicated damage primarily to the left fender, left door assembly, left mirror assembly, left body side molding, left handle, and the left uniside assembly; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproductions of the subject 2005 Honda Civic

Figure 2: Reproductions of the incident 1999 Chevrolet Lumina

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Honda Civic and geometric measurements of a 2005 Honda Civic revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour angled frontal barrier impact to the front of a Honda Civic would result in significant and visibly noticeable crush to the left front of the subject vehicle's left front structure, with a residual crush of 7.5 inches angling to zero inches at the center of the vehicle. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the left front of the incident Honda Civic indicates that the subject incident is consistent with a collision resulting in a Delta-V below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Furthermore, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Civic, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[18] The IIHS tested a 2001 Honda Civic, essentially the same vehicle as a 2005 Honda Civic. In a five mile-per-hour angled frontal impact into a flat barrier the test Honda sustained damage primarily to the front bumper cover, front bumper reinforcement, radiator support panel, front fender and required a frame pull. The incident Honda sustained damage primarily to the left lens and housing, impact bar, left stiffener, bumper cover, front retainers, hood, left fender, left side support, left side panel, upper tie bar, and required a frame pull. Thus, because the test Honda in the IIHS angled frontal impact test sustained comparable damage, the energy transfer and severity of the IIHS impact is more comparable to the severity of the subject incident and places the subsequent frontal impact of the subject incident closer to the test speed of 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V significantly below 10 miles-per-hour and comparable to 5 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration

11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several Reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

associated with a 10-mile-per-hour and 5-mile-per-hour impact are 3.0g and 1.5g respectively.[19] By the laws of physics, the average acceleration experienced by the subject Honda in which Ms. Torres-Mendoza was seated was less than 3.0g and comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Torres-Mendoza experiences 1g of loading while in a sedentary state. Therefore, Ms. Torres-Mendoza experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Torres-Mendoza in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Torres-Mendoza testified that she was able to lift 30-50 lbs, perform cardiovascular exercise, and clean her house prior to the subject incident. Additionally, Ms. Torres-Mendoza testified that she worked as a caregiver, which required her to prepare meals and transport the patient to appointments. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average 3g associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which Ms. Torres-Mendoza was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Torres-Mendoza's claimed injuries in the subject incident.

Kinematic Analysis:

According to State of Washington Police Traffic Collision Report and other available documents, Ms. Torres-Mendoza was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Torres-Mendoza's principle direction of motion would be forward and slightly leftward, relative to her vehicle. Ms. Torres-Mendoza testified that her body moved back into the seat at impact.

This is contrary to the actual motions due to the subject incident. The laws of physics dictate that left front contact to the subject Honda with the left side of the incident Chevrolet would have caused the subject Honda to decelerate and move slightly rightward. Based upon my review of

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19 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

20 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation* 42:25-30.

motor vehicle crash tests, results cited in the scientific literature,[22,23] and the laws of physics, had the forces generated during this interaction been sufficient to overcome the muscle reaction forces of Ms. Torres-Mendoza, her body would have moved forward and slightly leftward relative to the subject vehicle's interior. The three-point restraint that Ms. Torres-Mendoza was reportedly wearing would have locked when the vehicle accelerations exceeded 0.7g,[24] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Ms. Torres-Mendoza, as well as the passive muscle resistance of her arms would have acted in conjunction with her three-point restraint to limit body motion. Provided the low accelerations of the subject incident, and the supports described, the bodily response of Ms. Torres-Mendoza would have been limited to within normal physiological limits.

Findings:

1. On January 15, 2011, Ms. Guadalupe Torres-Mendoza was the belted driver of a 2005 Honda Civic that was contacted in the left front at low speed.
2. The change in velocity was significantly below 10 miles-per-hour and comparable to 5 miles-per-hour with average accelerations below 3.0g and more comparable to 1.5g.
3. The acceleration experienced by Ms. Torres-Mendoza was within the limits of human tolerance, the personal tolerance levels of Ms. Torres-Mendoza and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Torres-Mendoza was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?

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[22] Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

[23] Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

[24] Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

[25] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[26] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament, (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Torres-Mendoza was diagnosed with a cervical sprain/strain.

As described previously, the vehicle interaction would have caused rearward acceleration of the subject Honda. Had the forces generated been sufficient to overcome Ms. Torres-Mendoza's muscle reaction forces, her body would have moved forward and slightly leftward relative to the subject vehicle's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Honda. Ms. Torres-Mendoza's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[27] A kinematic analysis of Ms. Torres-Mendoza's response to the subject incident demonstrated that her overall head motion would have been relatively minimal.[28,29] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[30] As a result, Ms. Torres-Mendoza's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[31]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[32] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of

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[27] Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

[28] Araszewski, M., Roenitz, E., and Toor, A., (1999) Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts, (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

[29] Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004) Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts, (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

[30] Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

[31] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[32] Nielsen, G.P., Gough, J.P., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[33] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine injury potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical injury are greater that that associated with the subject incident.[34,35] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[36] None of the participants reported any chronic cervical injuries. Arbogast et al.[37] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[38] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[39,40] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Torres-Mendoza cannot be made.

Lumbar Spine

According to the available documents, Ms. Torres-Mendoza was diagnosed with a lumbar sprain/strain.

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33 Siegmund, G., and Williamson, P., (1993) "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

34 Ivancic, P.C., Ito, S., Panjabi, M.M., et al., (2005) "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

35 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al., (2005) "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

36 Chandler, R.F., and Christian, R.A., (1970) Crash Testing of Humans in Automobile Seats, (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

37 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009) Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests, (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

40 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

In this type of collision, the motion of Ms. Torres-Mendoza's thoracic and lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Ms. Torres-Mendoza's muscle reaction forces, her body would have moved forward and slightly left relative to the subject vehicle's interior. As described previously, Ms. Torres-Mendoza reportedly was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[41] Therefore, Ms. Torres-Mendoza's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Ms. Torres-Mendoza's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[42] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[43] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[44] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[45] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[46] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic injury. The subject incident had an average acceleration below 3.0g and comparable to 1.5g. Ms. Torres-Mendoza's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded

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41 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

42 Nielsen, G.P., Gough, J.P., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

43 Siegmund, G., and Williamson, P., (1993) "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

44 Chandler, R.F., and Christian, R.A., (1970) Crash Testing of Humans in Automobile Seats, (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

45 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009) Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests, (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

46 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

the personal tolerance limits of Ms. Torres-Mendoza, a causal link between the subject incident and claimed lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On January 15, 2011, Ms. Guadalupe Torres-Mendoza was the belted driver of a 2005 Honda Civic that was contacted in the left front at low speed.
2. The severity of the subject incident was consistent with a Delta-V significantly below 10 miles-per-hour and comparable to 5 miles-per-hour with an average acceleration below 3.0g and comparable to 1.5g for the subject 2005 Honda Civic in which Ms. Torres-Mendoza was seated.
3. The acceleration experienced by Ms. Torres-Mendoza was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupant's body forward and slightly leftward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Torres-Mendoza's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Torres-Mendoza's claimed lumbar spine injuries. As such, a causal relationship between the subject incident and the lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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May 31, 2012

Melinda Wieder, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Christensen, Lisa v. Kyle Bock*
Claim No.: 478030634008
ARCCA Case No.: 3271-174

Dear Ms. Wieder:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Lisa Christensen. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on June 23, 2010, Ms. Lisa Christensen was the restrained driver of a 1998 Ford Expedition traveling eastbound on N Levee Road East in Fife, Washington. Mr. Kyle Bock was the restrained driver of a 2008 Ford Focus that was traveling on N Levee Road East directly behind the Ford Expedition. According to the available documents, the Ford Expedition was stopped preparing to turn left and the Ford Focus failed to stop in time. As a result, the front of the incident Ford Focus contacted the rear of the subject Ford Expedition. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 3304216
- Thirteen (13) color photographic reproductions of the subject vehicle Ford Expedition
- Five (5) color photographic reproductions of the incident vehicle 2008 Ford Focus
- Carstar – Barrett's Collision Center, Inc. repair estimate for the subject 1998 Ford Expedition [June 24, 2010]
- Art Gamblin Motors repair estimate for the incident 2008 Ford Focus [July 1, 2010]
- Recorded Statement Transcript of Kyle Kenneth Bock [June 28, 2010]
- Recorded Statement Transcript of Lisa Christensen [June 25, 2010]
- Medical Records pertaining to Lisa Christensen
- VinLink data sheet for the subject 1998 Ford Expedition
- Expert AutoStats data sheets for a 1998 Ford Expedition
- VinLink data sheet for the incident 2008 Ford Focus
- Expert AutoStats data sheets for a 2008 Ford Focus

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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[6] Robbins, D.H., et al., (1983). Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. Christensen claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Christensen was occupying;
3. Determine Ms. Christensen's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Christensen's response to the subject incident;
5. Evaluate Ms. Christensen's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Christensen has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimate of the subject Ford Expedition and incident Ford Focus in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Ford Expedition and the Ford Focus, where the primary points of impact to the incident Ford Focus and the subject Ford Expedition were to the front and rear, respectively.

The damage estimate of the subject Ford Expedition indicated damage primarily to the left and right quarter panel, rear bumper assembly, frame assembly, and required a four wheel alignment; which is consistent with the reviewed photographic reproductions (Figure 1). The damage

[7] Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

[10] Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

estimate of the incident Ford Focus indicated damage primarily to the front bumper cover, lower grille, left and right outer reinforcement, energy absorber, bumper cover retainer, impact bar, grille assembly, left and right headlamp assembly, radiator support, radiator mount bracket, AC condenser, radiator, hood, hood latch, left and right fender, and the left and right upper rail; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproductions of the subject 1998 Ford Expedition

Figure 2: Reproductions of the incident 2008 Ford Focus

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Ford Expedition and geometric measurements of a 1998 Ford Expedition revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Ford Expedition would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 4.0 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Ford Expedition indicates that the subject incident is consistent with a collision resulting in a Delta-V below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour for the subject Ford Expedition. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[18] By the laws of physics, the average acceleration experienced by the subject Ford Expedition in which Ms. Christensen was seated was less than 3.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Christensen experiences 1g of loading while in a sedentary state. Therefore, Ms. Christensen experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Christensen in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, Ms. Christensen works cleaning houses for a living, which requires her to bend over and be on her knees scrubbing. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
16 EDCRASH, Engineering Dynamics Corp.
17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.
19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Ford Expedition in which Ms. Christensen was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Christensen's claimed injuries in the subject incident.

Kinematic Analysis:

According to the State of Washington Police Traffic Collision Report and other available documents, Ms. Christensen was wearing the three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Christensen's principle direction of motion would be rearward, relative to her vehicle. Additionally, the available documents indicate Ms. Christensen was tossed forward then backward.

This described motion is contrary to the actual motions of the subject incident. The laws of physics dictate that when the incident Ford Focus contacted the rear of the subject Ford Expedition, had there been enough energy transferred to initiate motion, the Ford Expedition would have been pushed forward causing Ms. Christensen's seat to move forward relative to her body, which would result in Ms. Christensen moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Christensen and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Christensen would have been limited to well within the range of normal physiological limits.

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20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation* 42:25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

Findings:

1. On June 23, 2010, Ms. Lisa Christensen was the belted driver of a 1998 Ford Expedition that was contacted in the rear at low speed.
2. The change in velocity was less than 10 miles-per-hour with average accelerations less than 3.0g.
3. The acceleration experienced by Ms. Christensen was within the limits of human tolerance, the personal tolerance levels of Ms. Christensen and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Christensen was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Christensen was diagnosed with a cervical sprain/strain.

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[24] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[25] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford Expedition would be pushed forward and Ms. Christensen would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1999 Ford Expedition, essentially the same vehicle as a 1998 Ford Expedition, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30.5 inches. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Christensen's age (39 years), height (65 inches) and weight (148 lbs), Ms. Christensen has a normal seated height of 33.0 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Christensen and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Christensen in the subject incident. The subject incident had an

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[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[28] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

[29] Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

average acceleration less than 3.0g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. Christensen would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Christensen cannot be made.

Thoracic Spine

According to the available documents, Ms. Christensen was diagnosed with a thoracic sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

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30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation* 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 3.0g. Ms. Christensen's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Christensen, a causal link between the subject incident and claimed thoracic injuries cannot be made.

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[34] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[35] Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[36] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[37] Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[38] Nordin M. and Frankel V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[39] Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* **7**(3): 184-191.

[40] Schibye, B., Sogaard, K., et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics* 16: 549-559.

[41] Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[42] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation* 42: 410-415.

[43] Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine* 29(20): 2319-2329.

ARCCA

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On June 23, 2010, Ms. Lisa Christensen was the belted driver of a 1998 Ford Expedition that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour with an average acceleration less than 3.0g for the subject 1998 Ford Expedition in which Ms. Christensen was seated.
3. The acceleration experienced by Ms. Christensen was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Christensen's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Christensen's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Christensen's claimed thoracic spine injuries. As such, a causal relationship between the subject incident and the thoracic injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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June 22, 2012

Claudia Shannon, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Sanders, Charlie v. Joyce Kim and John Doe Kim*
Claim No.: 308708793018
ARCCA Case No.: 3271-188

Dear Ms. Shannon:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Charlie Sanders. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on April 15, 2009, Mr. Charlie Sanders was the restrained driver of a 2006 Chevrolet Express Van traveling southbound on State Route 525 in Mukilteo, Washington. Ms. Joyce Kim was the restrained driver of a 1998 Nissan Maxima traveling on State Route 525 directly behind the Chevrolet. According to the available documents, the Chevrolet was stopped for traffic at a red light and was struck from behind by the incident Nissan. As a result, the front bumper of the incident Nissan contacted the rear of the subject Chevrolet. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 2668702
- Two (2) color photographic reproductions of the subject 2006 Chevrolet Express Van
- Eight (8) color photographic reproductions of the incident 1998 Nissan Maxima
- Eastmont Auto Rebuild, Inc. repair estimate for the subject 2006 Chevrolet Express Van
- Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff, *Charlie Sanders vs. Joyce Kim and John Doe Kim*
- Plaintiff's Statement of Damages, *Charlie Sanders vs. Joyce Kim and John Doe Kim* [February 8, 2012]
- Recorded Statement Transcript of Charlie Sanders [April 28, 2009]
- Medical Records pertaining to Charlie Sanders
- VinLink data sheet for the subject 2006 Chevrolet Express Van
- Expert AutoStats data sheets for a 2006 Chevrolet Express Van
- VinLink data sheet for the incident 1998 Nissan Maxima
- Expert AutoStats data sheets for a 1998 Nissan Maxima

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Mr. Sanders claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Sanders was occupying;
3. Determine Mr. Sanders's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Sanders's response to the subject incident;
5. Evaluate Mr. Sanders's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Sanders has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Chevrolet Express Van and incident Nissan Maxima in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Chevrolet and the Nissan, where the primary points of impact to the incident Nissan and the subject Chevrolet were to the front and rear, respectively.

The damage estimate of the subject Chevrolet indicated there was damage to the rear bumper assembly; which is consistent with the reviewed photographic reproductions (Figure 1). The reviewed photographic reproductions of the incident Nissan Maxima depict damage to the front bumper cover and license plate (Figure 2).

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7 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

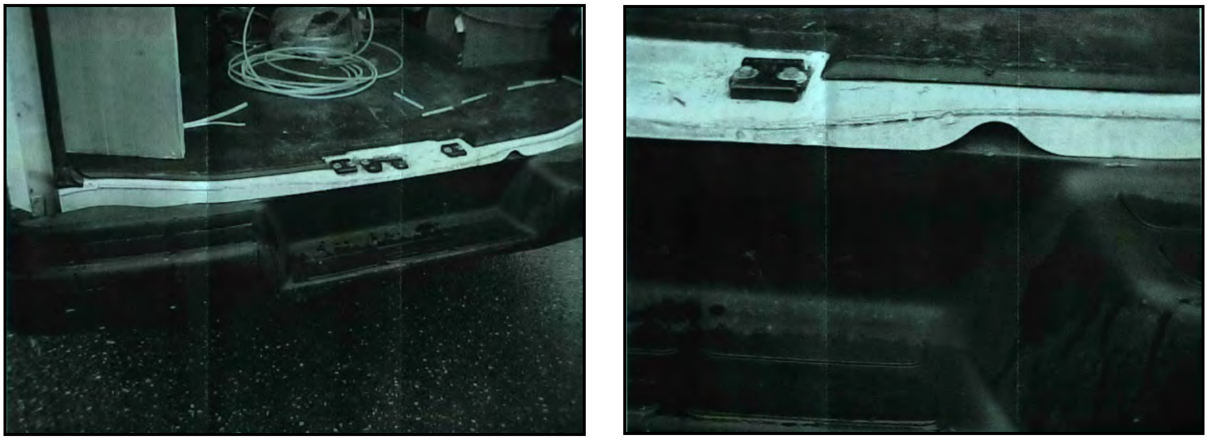

Figure 1: Reproductions of photographs of the subject 2006 Chevrolet Express Van

Figure 2: Reproductions of photographs of the incident 1998 Nissan Maxima

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Nissan can be used to resolve the loads sustained by the subject Chevrolet. That is, the forces sustained by the incident Nissan are equal and opposite to those of the subject Chevrolet.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs of the incident Nissan Maxima and geometric measurements of a 1998 Nissan Maxima revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Nissan Maxima would result in significant and visibly noticeable crush across the entirety of the incident vehicle's front structure, with a residual crush of 2.5 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the front of the incident Nissan indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the above analysis is consistent with an energy-based crash analysis of a 2006 Chevrolet Express Van.

Furthermore, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Nissan Maxima, defined by the photographic reproductions, was used to perform a damage threshold speed change analysis.[18] The IIHS tested a 1998 Nissan Maxima in a five mile-per-hour frontal impact into a flat barrier. The test Nissan sustained damage to the front bumper cover, bumper reinforcement bar, and bending of the steel support below the grill. There was no evidence of bending of the steel support below the grill to the incident Kim Nissan Maxima. Thus, because the test Nissan Maxima in the IIHS frontal impact test sustained greater damage, the severity of the IIHS impact is more comparable to the severity of the subject incident and places the subject incident speed comparable to 5 miles-per-hour.

Review of the vehicle damage, incident data, published literature, engineering analyses, the conservation of momentum and my experience indicates an incident resulting in a Delta-V below 5.7 miles-per-hour for the subject Chevrolet Express Van. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5.7 mile-per-hour impact is 1.7g.[19] By the laws of physics, the average acceleration experienced by the subject Chevrolet in which Mr. Sanders was seated was less than 1.7g.

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

19 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Mr. Sanders experiences 1g of loading while in a sedentary state. Therefore, Mr. Sanders experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Sanders in his daily life would have increased the loading to his body beyond the sedentary 1g. According to the available documents, Mr. Sanders worked as a sales manager/route manager which required him to move heavy machinery along with twisting and stooping as a part of his job. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Chevrolet in which Mr. Sanders was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Sanders's claimed injuries in the subject incident.

Kinematic Analysis:

According to the State of Washington Police Traffic Collision Report, Mr. Sanders was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Sanders's principle direction of motion would be rearward, relative to his vehicle.

The laws of physics dictate that when the incident Nissan contacted the rear of the subject Chevrolet, had there been enough energy transferred to initiate motion, the Chevrolet would have been pushed forward causing Mr. Sanders's seat to move forward relative to his body, which would result in Mr. Sanders moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Sanders and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[22,23,24] Any rebound would have been within the range of protection

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20 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

22 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

23 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

24 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Sanders would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 15, 2009, Mr. Charlie Sanders was the belted driver of a 2006 Chevrolet Express Van that was contacted in the rear at low speed.
2. The change in velocity was below 5.7 miles-per-hour with average accelerations less than 1.7g.
3. The acceleration experienced by Mr. Sanders was within the limits of human tolerance, the personal tolerance levels of Mr. Sanders and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Sanders was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

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[25] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[26] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Cervical Spine

According to the available documents, Mr. Sanders was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Chevrolet would be pushed forward and Mr. Sanders would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 Chevrolet Express Van showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.0 inches. Additionally, according to the available documents, there is a pillow pad above the headrest for further protection in the subject vehicle. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Sanders's age (22 years), height (79 inches) and weight (178 lbs), Mr. Sanders has a normal seated height of 37.9 inches. Accounting for seat compression, and a noted cushion pad above the head restrain, the seat is tall enough to have prevented hyperextension of Mr. Sanders and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-

[27] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[28] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[29] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

[30] Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

end impacts of comparable or greater severity to that experienced by Mr. Sanders in the subject incident. The subject incident had an average acceleration of less than 1.7g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Mr. Sanders would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Mr. Sanders cannot be made.

Thoracic and Lumbar Spine

According to the available documents, Mr. Sanders was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

31 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

32 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

34 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 1.7g. Mr. Sanders's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Sanders, a causal link between the subject incident and claimed thoracic and lumbar spine injuries cannot be made.

35 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

36 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

39 Nordin M. and Frankel V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

40 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine* **7**(3): 184-191.

41 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

42 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

43 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

44 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 15, 2009, Mr. Charlie Sanders was the belted driver of a 2006 Chevrolet Express Van that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V below 5.7 miles-per-hour with an average acceleration less than 1.7g for the subject 2006 Chevrolet Express Van in which Mr. Sanders was seated.
3. The acceleration experienced by Mr. Sanders was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Sanders's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Mr. Sanders's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Mr. Sanders's claimed thoracic and lumbar injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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EXHIBIT
PENGAD 800-631-6989
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June 29, 2012

Angela Chang, Esquire
Angela Chang, Attorney-at-Law
901 Fifth Avenue, Suite 830
Seattle, WA 98164

Re: *LaBlanc, Aimee v. Jae-Young Kim*
File No.: 0178977641.1
ARCCA Case No.: 4054-014

Dear Ms. Chang:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Aimee LaBlanc. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

ARCCA

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on October 2, 2010, Ms. Aimee LaBlanc was the restrained driver of a 1998 Dodge Neon traveling westbound on State Route 253 in Shoreline, Washington. Mr. Jae-Young Kim was the driver of a 2010 Hyundai Veracruz traveling westbound on State Route 253 directly behind the Dodge. According to the available documents, the Dodge was stopped for traffic at a stop light and was struck from behind by the incident Hyundai. As a result, the front of the incident Hyundai contacted the rear of the subject Dodge. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washing Police Traffic Collision Report, Report No. E069962
- Thirty-five (35) color photographic reproductions of the subject 1998 Dodge Neon
- Thirty (30) color photographic reproductions of the incident 2010 Hyundai Veracruz
- Allstate Insurance Company repair estimate for the subject 1998 Dodge Neon [October 5, 2010]
- Allstate Insurance Company supplement 1 estimate for the subject 1998 Dodge Neon [October 22, 2010]
- Allstate Insurance Company repair estimate for the incident 2010 Hyundai Veracruz [October 8, 2010]
- Deposition Transcript of Aimee J. LaBlanc
- Medical Records pertaining to Aimee LaBlanc
- VinLink data sheet for the subject 1998 Dodge Neon
- Expert AutoStats data sheets for a 1998 Dodge Neon
- Expert AutoStats data sheets for a 1997 Dodge Neon
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1997 Dodge Neon
- VinLink data sheet for the incident 2010 Hyundai Veracruz
- Expert AutoStats data sheets for a 2010 Hyundai Veracruz

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. LaBlanc claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. LaBlanc was occupying;
3. Determine Ms. LaBlanc's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. LaBlanc's response to the subject incident;
5. Evaluate Ms. LaBlanc's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. LaBlanc has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic Spine
    - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Dodge Neon and incident Hyundai Veracruz in association with accepted engineering methodologies. According to the available documents, the subject incident

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

was a rear impact between the Dodge and the Hyundai, where the primary points of impact to the incident Hyundai and the subject Dodge were to the front and rear, respectively.

The damage estimate of the subject Dodge Neon indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). The reviewed photographic reproductions of the incident Hyundai depicted damage to the license plate (Figure 2). Additionally, the State of Washington Police Traffic Collision Report indicated there was no visible damage to either vehicle.

Figure 1: Reproductions of photographs of the subject 1998 Dodge Neon

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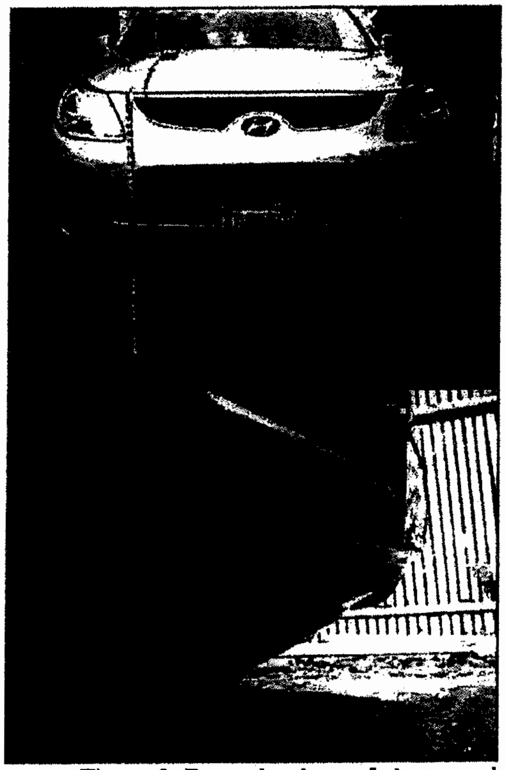
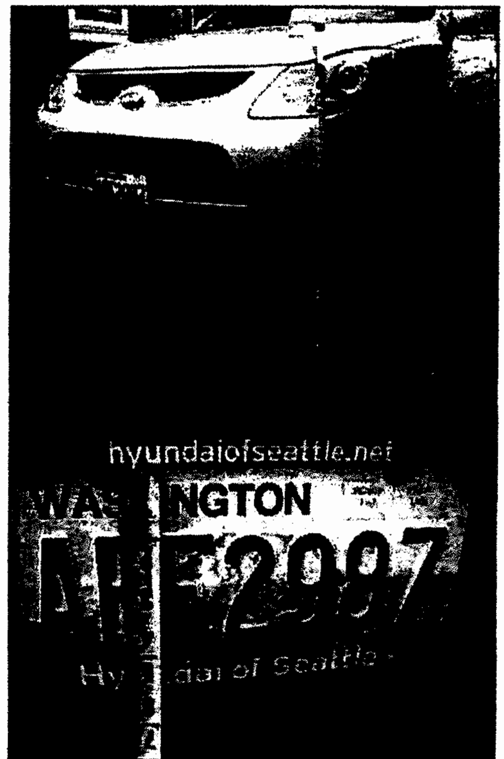

Figure 2: Reproductions of photographs of the incident 2010 Hyundai Veracruz

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Dodge Neon, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 1997 Dodge Neon, essentially the same vehicle as a 1998 Dodge Neon, in a five mile-per-hour rear impact into a flat barrier. The test Dodge sustained damage to the left and right lower rear body panel and rear bumper absorber. The primary damage to the subject Dodge was to the rear bumper cover. Thus, because the test Dodge in the IIHS rear impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1998 Dodge Neon.[12,13,14,15,16,17]

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11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Dodge Neon. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[18] By the laws of physics, the average acceleration experienced by the subject Dodge in which Ms. LaBlanc was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. LaBlanc experiences 1g of loading while in a sedentary state. Therefore, Ms. LaBlanc experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. LaBlanc in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. LaBlanc testified that prior to the subject incident she was capable of working at her job 30 hours per week which included preparing food, taking out the garbage, opening and closing the store. Additionally, she testified that she was able to perform Pilates or aerobics every night and household duties. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Dodge in which Ms. LaBlanc was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. LaBlanc's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. LaBlanc was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. LaBlanc's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. LaBlanc testified she was unaware for the impending impact.

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15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences*, 42:25-30.

The laws of physics dictate that when the incident Hyundai contacted the rear of the subject Dodge, had there been enough energy transferred to initiate motion, the Dodge would have been pushed forward causing Ms. LaBlanc's seat to move forward relative to her body, which would result in Ms. LaBlanc moving rearward relative to the interior of the subject vehicle. This interaction between Ms. LaBlanc and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. LaBlanc would have been limited to well within the range of normal physiological limits.

Findings:

1. On October 2, 2010, Ms. Aimee LaBlanc was the belted driver of a 1998 Dodge Neon that was contacted in the rear at low speed by a 2010 Hyundai Veracruz.
2. The change in velocity was less than 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Ms. LaBlanc was within the limits of human tolerance, the personal tolerance levels of Ms. LaBlanc and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. LaBlanc was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A. F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. LaBlanc was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Dodge would be pushed forward and Ms. LaBlanc would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1998 Plymouth Neon, essentially the same vehicle as a 1998 Dodge Neon, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 28.0 inches in the "full down" position and 32.0 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. LaBlanc's age (33 years), height (63 inches) and weight (103 lbs), Ms. LaBlanc has a normal seated height of 32.1 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. LaBlanc and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. LaBlanc in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. LaBlanc would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. LaBlanc cannot be made.

Thoracic Spine

According to the available documents, Ms. LaBlanc was diagnosed with a thoracic sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute

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28 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 1.5g. Ms. LaBlanc's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises

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34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

35 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. LaBlanc, a causal link between the subject incident and claimed thoracic injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On October 2, 2010, Ms. Aimee LaBlanc was the belted driver of a 1998 Dodge Neon that was contacted in the rear at low speed by a 2010 Hyundai Veracruz.
2. The severity of the subject incident was consistent with a Delta-V less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 1998 Dodge Neon in which Ms. LaBlanc was seated.
3. The acceleration experienced by Ms. LaBlanc was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. LaBlanc's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no injury mechanism present in the subject incident to account for Ms. LaBlanc's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. LaBlanc's claimed thoracic spine injuries. As such, a causal relationship between the subject incident and the thoracic injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer
BWP/llr

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[43] Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

EXHIBIT V-22

TO

DECLARATION OF KARI LESTER

DOMINGUEZ V. SCHULTZ

Case No. 15-2-31277-4

ARCCA, INCORPORATED
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EXHIBIT
PENGAD 800-631-6989
Probst 22
5-23-17 ahy

August 24, 2012

Dylan Becker, Esquire
Barger Law Group, PC
4949 Meadows Road, Suite 620
Lake Oswego, OR 97035

Re: *Green, Valenna v. Gabriela Warren*
ARCCA Case No.: 4202-006

Dear Mr. Becker:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Valenna Green. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on June 25, 2009, Ms. Valenna Green was the driver of a 1992 Saturn SL2 traveling westbound on NE 78th Street at the intersection with NE 72nd Avenue in Walnut Grove, Washington. Ms. Gabriela Warren was the driver of a 1997-2003 model Ford Escort traveling westbound on NE 78th Street directly behind the Saturn. According to the available documents, the Saturn was stopped preparing to turn left and was struck from behind by the Ford. As a result, the front of the incident Ford contacted the rear of the subject Saturn. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nineteen (19) color photographic reproductions of the subject 1992 Saturn SL2
- Four (4) color photographic reproductions of the incident 1997-2003 Ford Escort
- Geico Supplement of Record 1 with Summary for the subject 1992 Saturn SL2 [July 10, 2009]
- Complaint, *Valenna Green v. Gabriela Warren* [January 19, 2011]
- Deposition of Valenna Green [July 19, 2011]
- VinLink data sheet for the subject 1992 Saturn SL2
- Expert AutoStats data sheets for a 1992 Saturn SL2
- Expert AutoStats data sheets for a 1993 Saturn SL2
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1993 Saturn SL2
- Expert AutoStats data sheets for a 1997 Ford Escort
- Expert AutoStats data sheets for a 2003 Ford Escort
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1997 Ford Escort

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Saturn SL2 and incident Ford Escort in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Saturn SL2 and the Ford Escort, where the primary points of impact to the incident Ford and the subject Saturn were to the front and rear, respectively.

The damage estimate of the subject Saturn SL2 indicated damage primarily to the rear bumper cover and right trunk filler panel; which is consistent with the photographic reproductions of the subject Saturn (Figure 1). Note: the repair estimate for the subject Saturn indicates there was prior damage to the trunk lid area. The reviewed photographic reproductions of the incident Ford depict damage to the front bumper cover and license bracket area (Figure 2).

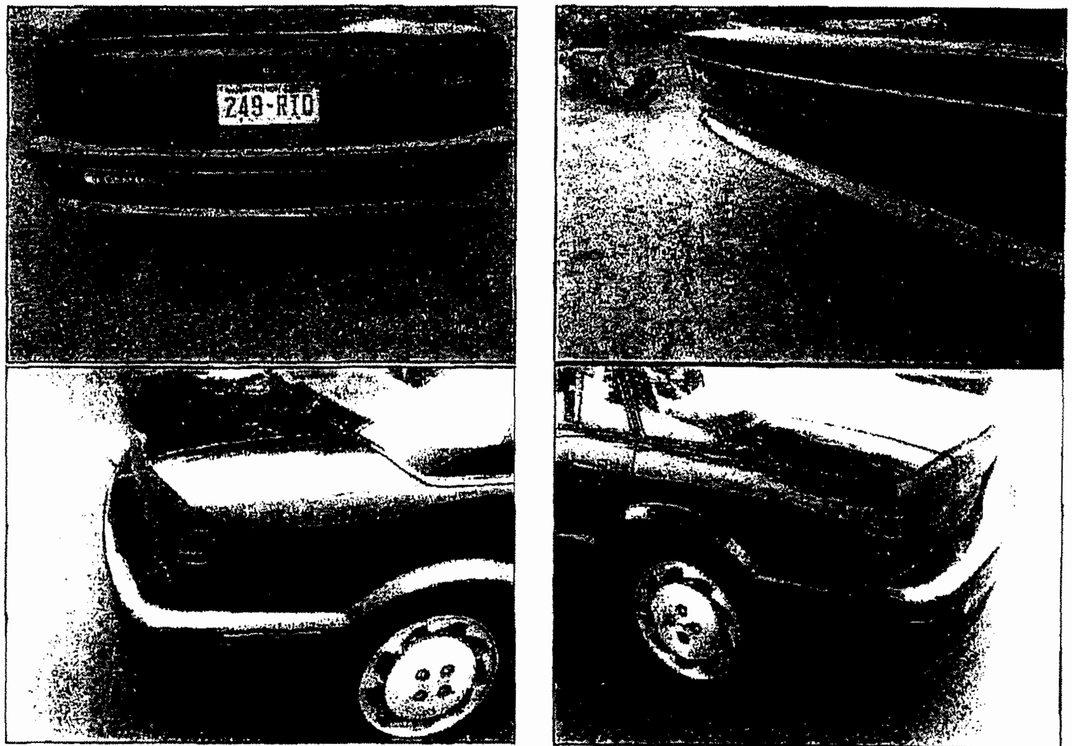

Figure 1: Reproductions of the subject 1992 Saturn SL2

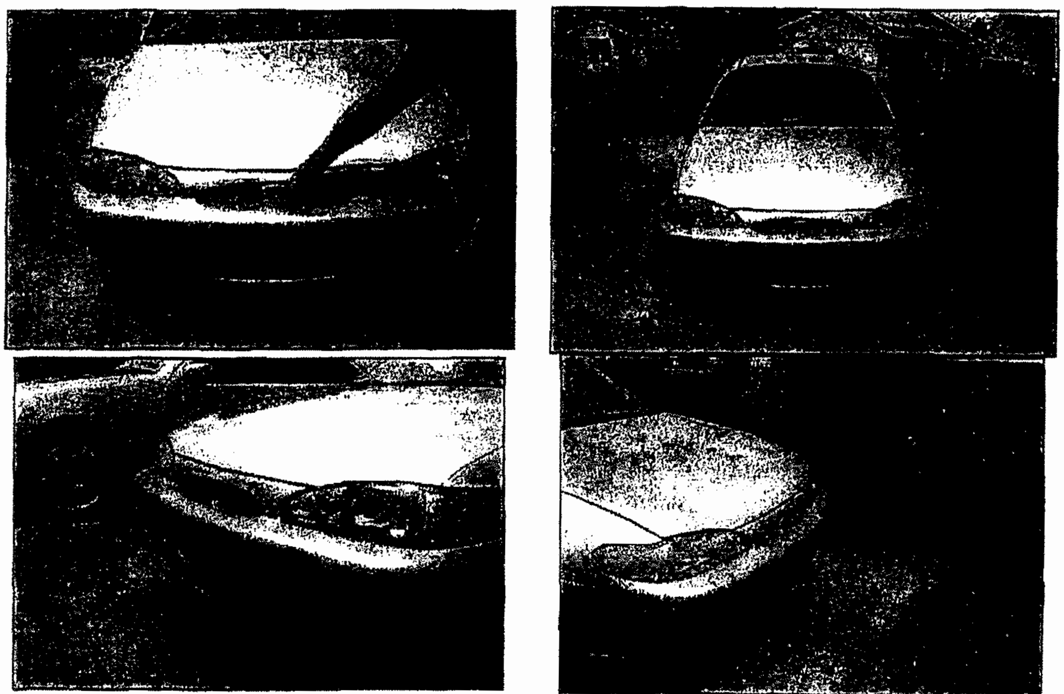

Figure 2: Reproductions of the incident 1997-2003 Ford Escort

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Saturn SL2, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[6] The IIHS tested a 1993 Saturn SL2, essentially the same vehicle as a 1992 Saturn SL2, in a five mile-per-hour rear impact into a flat barrier. The test Saturn sustained damage to the rear bumper absorber. The primary damage to the subject Saturn was to the rear bumper cover and right trunk filler panel. Thus, because the test Saturn in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1992 Saturn SL2.[7,8,9,10,11,12,13]

The IIHS tested a 1997 Ford Escort in a five mile-per-hour frontal impact into a flat barrier. The test Ford sustained deformation to the bumper bar, radiator support and left and right inner fender assemblies. While a repair estimate for the incident Ford was not available, the reviewed photographs did not indicate any deformation to the above mentioned components. Thus, because the test Ford in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is comparable if not greater to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1997 Ford Escort, essentially that same vehicle as all model year 1997 through 2003 Ford Escorts.[14,15,16,17,18,19,20]

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6 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

7 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

9 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

10 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

11 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

12 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

13 Insurance Institute for Highway Safety Low-Speed Crash Tests (1997). 1997 Ford Escort, Arlington, VA. Insurance Institute for Highway Safety.

14 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

17 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

18 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Insurance Institute for Highway Safety Low-Speed Crash Tests (1997). 1997 Ford Escort, Arlington, VA. Insurance Institute for Highway Safety.

ARCCA

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Saturn SL2. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[21] By the laws of physics, the average acceleration experienced by the subject Saturn in which Ms. Green was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Green experiences 1g of loading while in a sedentary state. Therefore, Ms. Green experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Green in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[22] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[23] Ms. Green was noted to be a infant teacher/employee of a child care center. This would entail bending and other movements, sitting in chairs, and potentially lifting substantial objects that would exceed the range of motion and/or forces of the subject incident.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Saturn SL2 in which Ms. Green was seated was well within the limits of human tolerance. West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[24] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[25] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean

21 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

22 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

23 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

24 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

25 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

accelerations between 1.8g and 2.6g, without sustaining any severe cervical, thoracic, or lumbar injuries.[26] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[27] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Green in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[28,29]

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On June 25, 2009, Ms. Valenna Green was the driver of a 1992 Saturn SL2 that was contacted in the rear at low speed by a 1997-2003 model Ford Escort.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with average acceleration comparable to 1.5g for the subject 1992 Saturn SL2 in which Ms. Green was seated.
3. The acceleration experienced by Ms. Green was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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26 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

27 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

28 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation,* 42:25-30.

29 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

ARCCA INCORPORATED
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June 29, 2012

Sarah Sato, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Williams, Rachel v. Edward and Duse McLean*
Claim No.: 559105104008
ARCCA Case No.: 3271-162

Dear Ms. Sato:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Rachel Williams. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering. 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on May 17, 2009, Ms. Rachel Williams was the restrained driver of a 2001 Ford Focus traveling on the SR 520 Montlake onramp in Seattle, Washington. Mr. Edward McLean was the driver of a 1990 Toyota Camry traveling directly behind the Ford. According to the available documents, the Ford was stopped for traffic and was struck from behind by the incident Toyota. As a result, the front bumper of the incident Toyota contacted the rear of the subject Ford. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nineteen (19) color photographic reproductions of the subject 2001 Ford Focus
- Twenty-one (21) color photographic reproductions of the incident 1990 Toyota Camry
- Safeco Insurance Company of Illinois repair estimate for the subject 2001 Ford Focus [June 2, 2009]
- Safeco Insurance Company of Illinois repair estimate for the incident 1990 Toyota Camry [June 2, 2009]
- Medical Records pertaining to Rachel Williams
- VinLink data sheet for the subject 2001 Ford Focus
- Expert AutoStats data sheets for a 2001 Ford Focus
- Expert AutoStats data sheets for a 2000 Ford Focus
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2000 Ford Focus
- VinLink data sheet for the incident 1990 Toyota Camry
- Expert AutoStats data sheets for a 1990 Toyota Camry
- ARCCA inspection of incident Toyota Camry, June 29, 2012

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. Williams claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Williams was occupying;
3. Determine Ms. Williams's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Williams's response to the subject incident;
5. Evaluate Ms. Williams's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Williams has reported the following injuries as a result of the subject incident:

- Lumbar Spine
  - Large disc extrusion at the L4-5 level
  - Small moderate disc extrusion at the L5-S1 level

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimate of the subject Ford Focus and incident Toyota Camry in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Ford and the Toyota, where the primary points of impact to the incident Toyota and the subject Ford were to the front and rear, respectively.

The damage estimate of the subject Ford Focus indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). There was no reported new damage for the incident Toyota Camry; which is consistent with the reviewed photographic reproductions (Figure 2).

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7 Nahum, A., Gomez M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

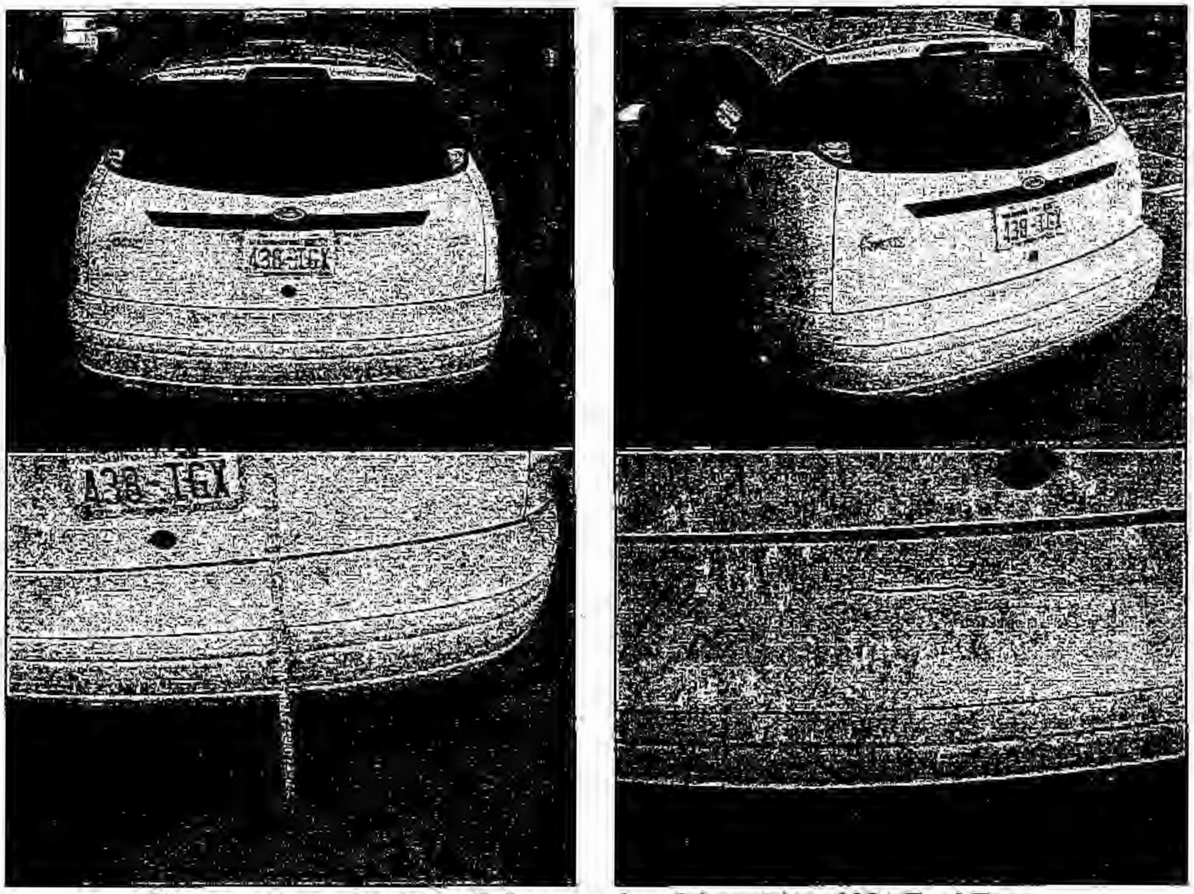

Figure 1: Reproductions of photographs of the subject 2001 Ford Focus

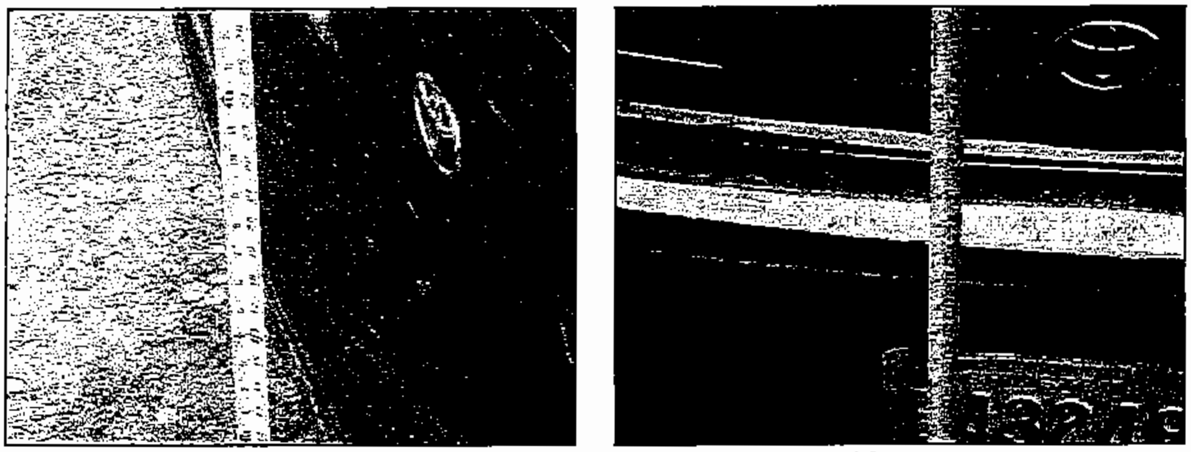

Figure 2: Reproductions of photographs of the incident 1990 Toyota Camry

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Ford Focus, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2000 Ford Focus, essentially the same vehicle as the subject 2001 Ford Focus, in a five mile-per-hour rear impact into a flat barrier. The test Ford sustained damage to the rear bumper cover, rear reinforcement bumper, rear body panel, rear floor pan and the left quarter panel. The primary damage to the subject Ford was to the rear bumper cover. Thus, because the test Ford in the IIHS rear impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 2001 Ford Focus.[12,13,14,15,16,17]

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Ford Focus. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour

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11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

impact is 1.5g.[18] By the laws of physics, the average acceleration experienced by the subject Ford Focus in which Ms. Williams was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Williams experiences 1g of loading while in a sedentary state. Therefore, Ms. Williams experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Williams in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, prior to the subject incident Ms. Williams worked part time as a hair dresser. Additionally, the documents indicate she participated in hot yoga and volleyball along with occasional hiking and snowboarding. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times hody weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Ford in which Ms. Williams was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Williams's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Williams was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Williams's principle direction of motion would be rearward, relative to her vehicle.

The laws of physics dictate that when the incident Toyota contacted the rear of the subject Ford, had there been enough energy transferred to initiate motion, the Ford would have been pushed forward causing Ms. Williams's seat to move forward relative to her body, which would result in Ms. Williams moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Williams and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

of her body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Williams would have been limited to well within the range of normal physiological limits.

Findings:

1. On May 17, 2009, Ms. Rachel Williams was the belted driver of a 2001 Ford Focus that was contacted in the rear at low speed by a 1990 Toyota Camry.
2. The change in velocity was less than 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Ms. Williams was within the limits of human tolerance, the personal tolerance levels of Ms. Williams and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Williams was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[26]

Lumbar Spine

According to an MRI of Ms. Williams's lumbar spine, dated November 3, 2009, there were findings consistent with a large subligamentous disc extrusion at L4-5 causing moderate central stenosis and lateral recess stenosis. Additionally, the MRI report showed findings consistent with a small moderate subligamentous disc extrusion at L5-S1 causing mild central stenosis.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the

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[26] White III, A. A. and M. M. Panjabi, (1990) Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

[27] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

Delta-V of the struck vehicle approximately 5 mph.[28] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[29] The subject incident had an average acceleration less than 1.5g. Ms. Williams's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[30,31,32,33,34] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[35] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[36]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Williams, a causal link between the subject incident and claimed lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On May 17, 2009, Ms. Rachel Williams was the belted driver of a 2001 Ford Focus that was contacted in the rear at low speed by a 1990 Toyota Camry.

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28 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

29 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

30 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

31 Nordin M. and Frankel V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

32 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3): 184-191.

33 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

34 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

35 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

36 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

ARCCA

2. The severity of the subject incident was consistent with a Delta-V less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 2001 Ford Focus in which Ms. Williams was seated.
3. The acceleration experienced by Ms. Williams was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Williams's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Williams's claimed lumbar spine injuries. As such, a causal relationship between the subject incident and the lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

BWP/llr

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December 18, 2012

Sarah Sato, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Williams, Rachel v. Edward and Duse McLean*
Claim No.: 559105104008
ARCCA Case No.: 3271-162

Dear Ms. Sato:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Rachel Williams. This letter is meant to supplement my report of June 29, 2012, regarding Rachel Williams. Furthermore, the results from the joint inspection of the incident Toyota Camry do not change my opinion of my previous analysis:

Clarification:

In the course of my analysis regarding Rachel Williams, the reviewed materials should have included the following:

- FutureForensics Inspection by Mark E. Olson [June 29, 2012]

Discussion:

In my report, dated June 29, 2012, I indicated that ARCCA, Inc. performed an inspection of the incident 1990 Toyota Camry. The report should have also noted the inspection was a joint inspection with Mark E. Olson from FutureForensics. The inspection of the incident Toyota does not changes my conclusions from my prior report, as I evaluated the subject incident based on the subject vehicle.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Toyota Camry can be used to resolve the loads sustained by the subject Ford Focus. That is, the forces sustained by the incident Toyota are equal and opposite to those of the subject Ford.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[1,2,3,4,5] Analyses of the photographs and the

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1 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

2 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

repair estimate of the incident Toyota Camry and geometric measurements of a 1990 Toyota Camry revealed the damage due to the subject incident. An engineering analysis[6] indicates that a single 10-mile-per-hour barrier impact to the front of a Toyota Camry would result in significant and visibly noticeable crush across the front of the incident vehicle's front structure, with a residual crush of 2.75 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[7] The lack of significant structural crush to the front of the incident Toyota Camry indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested several cars of the same era and manufacturer as the incident vehicle as well as vehicles from other manufacturers. In a five mile-per-hour frontal impact into a flat barrier the test vehicles all sustained damage to the front bumper, front reinforcement bars, and front brackets/supports among other parts in some frontal IIHS tests. Based on my joint inspection with Mark Olson, the primary damage to the incident Toyota was to the front bumper cover, front absorber, front reinforcement and required a frontal setup and measure for the core supports/rails. Thus, because the test vehicles in the IIHS frontal impact test sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed closer to 5 miles-per-hour.

Note: The complete vehicle history of the incident Toyota is unknown; however it was noted there was unrelated right front damage.

The inspection of the incident Toyota further confirmed my analysis and conclusions of the subject Ford within my report dated June 29, 2012.

Conclusions:

Based upon the additional information my opinions from my report dated June 29, 2012, have not changed.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

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3 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

4 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

5 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

6 EDCRASH, Engineering Dynamics Corp.

7 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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August 8, 2012

Theodore Miller, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Sams, Courtney and Jessica v. Carolyn Krocker*
Claim No.: 858687024008-201
ARCCA Case No.: 3271-156

Dear Mr. Miller

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Jessica Sams. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of both the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On January 2, 2010, Ms. Jessica Sams was the restrained driver of a 2005 Honda Civic traveling through the Papa Murphy's parking lot at 3726 Pacific Avenue Southeast in, Olympia, Washington. Ms. Carolyn Krocker was the driver of a 1992-1996 Toyota Camry backing out of a parking space perpendicular to the Honda. According to the available documents, the incident Toyota entered the area in which the Honda was traveling causing contact between the vehicles. As a result, the rear of the incident Toyota came into contact with the right rear side of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eleven (11) color photographic reproductions of the subject 2005 Honda Civic
- Nine (9) color photographic reproductions of the incident 1992-1996 Toyota Camry
- Gerber – Lacey repair estimate for the subject 2005 Honda Civic [January 8, 2010]
- Gerber – Lacey Supplement of Record 1 with Summary for the subject 2005 Honda Civic [March 22, 2010]
- Deposition Transcript of Jessica M. Sams [June 29, 2011]
- Deposition Transcript of Courtney Sams [April 12, 2012]
- Medical Records pertaining to Jessica Sams
- VinLink data sheet for the subject 2005 Honda Civic
- Expert AutoStats data sheets for a 2005 Honda Civic
- Expert AutoStats data sheets for a 1992-1996 Toyota Camry

Injury Summary:

According to the documents, Ms. Sams has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbosacral Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Accord and incident Toyota Camry in association with accepted engineering methodologies. According to the available documents, the subject incident was a side impact between the Honda and the Toyota, where the primary points of impact to the incident Toyota and the subject Honda were to the rear and right rear side, respectively.

The damage estimate of the subject Honda Accord indicated damage primarily to the right rear outer door panel, right body side molding, trim retainer, door edge moulding, and right quarter panel; which is consistent with the reviewed photographic reproductions. The reviewed photographic reproduction of the incident Toyota Camry depicted damage to the rear bumper cover.

According to Ms. Jessica Sams's testimony, the subject Honda did not move far at all and moved only inches. Additionally, Ms. Courtney Sams testified that the subject Honda was pushed a little and it felt like the wheels moved on the ground. Based upon a skid-to-stop analysis, 5 miles-per-hour impact would move the subject Honda forward in excess of one foot. This assumes that the brakes are applied for the entire time. Additionally this analysis is also consistent with an energy-based crush analyses of a 2005 Honda Civic.[6,7,8,9,10,11]

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of a nominal 5 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the peak acceleration associated with a 5 mile-per-hour impact is 2.3g.[12] By the laws of physics, the peak acceleration experienced by the subject Honda Accord in which Ms. Sams was seated was less than 2.3g.

The acceleration experienced due to gravity is 1g. This means that the body of Ms. Sams experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Jessica Sams testified that prior to the subject incident she would go camping, fishing, snowboarding, and running. Additionally, she testified that she worked as a preschool teacher; which required bending over and picking up the children. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[13] More dynamic events, such as running, jumping, or lifting weights, can increase short

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6 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
7 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
8 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
9 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
10 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
11 EDCRASH, Engineering Dynamics Corp.
12 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.
13 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the Honda in which Ms. Sams was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

Ms. Jessica Sams was wearing the available three-point restraint system at the time of the subject incident. During the lateral impact event, Ms. Sams's principle direction of motion would be rightward, relative to the subject vehicle with slight forward flexion. Additionally, Ms. Sams testified that her torso was partially turned to her right at the time of the subject incident.

The laws of physics dictate that when the incident Toyota contacted the subject Honda, the subject Honda would have accelerated primarily leftward and decelerated longitudinally. This process would have resulted in a rightward motion of Ms. Sams's body relative to the interior of the subject Honda. The lap and shoulder belt would have restrained Ms. Sams's pelvis and torso and would have coupled her motion to the subject Honda. The low accelerations in the subject incident and the restraint provided by the seatbelt system, then, were such that any motion of Ms. Sams would have been limited to well within the range of normal physiological limits.

Findings:

1. On January 2, 2010, Ms. Jessica Sams was the belted driver of a 2005 Honda Civic when the right rear side was contacted by a 1992-1996 Toyota Camry.
2. The contact between the two vehicles is consistent with a lateral impact for the Honda.
3. The change in velocity was a nominal 5 miles-per-hour with peak accelerations less than 2.3g.
4. The acceleration experienced by Ms. Sams was within the limits of human tolerance, the personal tolerance levels of Ms. Sams and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities.[14] The energy imparted to Ms. Sams was well within the limits of human tolerance, and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link Ms. Sams's reported injuries and the subject incident.[15,16]

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[14] Gushue, D., Probst, B., et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[15] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, in order for a strain/sprain type injury to occur to any tissue, significant motion, which produces stretching, is required. Of particular interest is whether the subject incident created any of the mechanisms or loads by which Ms. Sams's claimed injuries occur. Evaluation of the injury mechanisms will be addressed for the specific injuries claimed by Ms. Sams.

Cervical Spine

According to the available documents, Ms. Jessica Sams was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injury is causally related to the lateral impact event. There was no hyperextension mechanism present in the subject incident, there would only be right lateral bending and slight forward flexion due to the seated position of Ms. Sams at the time of the subject incident. The cervical spine is extremely tolerant to inertial loading which results in lateral bending. A simple explanation for this is that the body has a built-in head restraint. The head is limited in lateral bending by contact of the head to the shoulder and in flexion by contact with the chest. Live human subjects have regularly been exposed to g levels up to approximately 9.0g in lateral bending and 16.0g in forward flexion with no acute trauma, only transient, short term soreness.[17] The subject incident had a peak acceleration of less than 2.3g. Ms. Sams would not have been exposed to any loading or motion outside of the range of human tolerance. There was no injury mechanism present in the subject incident to account for Ms. Sams claimed cervical injuries. As stated previously, Ms. Sams regularly receives loading that exceeds the acceleration to her body in the subject incident.

Additionally, researchers such as Zaborowski and Ewing have conducted several investigations that exposed human volunteers to lateral impact accelerations.[18,19,20,21] In response to these tests, physical

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16 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

17 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

18 Zaborowski, A.B., (1964) Human Tolerance to Lateral Impact with Lap Belt Only, (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

19 Zaborowski, A.B., (1964) Lateral Impact Studies: Lap Belt Shoulder Harness Investigations, (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

20 Ewing, C., Thomas, D., et al., (1977) Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration, (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

complaints were transient in nature and none of the participants sustained or reported any cervical spine injuries. Fugger et al.[22] conducted lateral impacts with human volunteers. Physical complaints following these tests were noted following five tests, but complaints were transient in nature and consisted of back pain or slight headache that lasted a few minutes. Lateral impact research by Bailey et al.[23] again demonstrated that human volunteers sustained comparable severity lateral impacts without the onset of cervical spine injuries. These data are consistent with safe human exposure guidelines to lateral impact accelerations.[24,25]

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[26,27] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance. As the subject incident did not create the required injury mechanism and did not induce force magnitudes that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical injuries of Ms. Sams cannot be made.

Thoracic and Lumbosacral Spine

According to the available documents, Ms. Jessica Sams was diagnosed with back sprain/strain, also known as a thoracic and lumbosacral sprain/strain.

There is no reason to assume that the claimed thoracic and lumbosacral injuries are causally related to the lateral impact event. In a lateral impact events of the type seen here the pelvis, thoracic and lumbar spines of an occupant are limited in motion by the restraint system. The seatbelt would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatbelt system would also distribute the restraint forces over the torso and hips, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The seatbelt system would not allow for hyperflexion of Ms. Sams's thoracic and lumbar spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit forward with little flexion, unless one portion of the spine is supported with another portion unsupported. There would be a greater force and movement on

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21 Ewing, C., Thomas, D., et al., (1978) Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration, (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

22 Fugger, T.F., et al., (2002) Human Occupant Kinematics in Low Speed Side Impacts, (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

23 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

24 Eiband, A.M., (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

25 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

26 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

27 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

Ms. Sams's thoracic and lumbar spine when she sits down in a chair than what was produced in the subject incident.

Several investigators have considered the human response to lateral impacts. Research by Zaborowski,[28] subjected human volunteers restrained with only a lap belt to lateral impacts. The accelerations utilized during this investigation exceeded that of the subject incident and no permanent physiological changes were noted with physical complaints limited to minor or moderate transient pain. A follow up study again subjected human volunteers to lateral impacts with acceleration levels that exceeded that associated with the subject incident.[29] No permanent physiological changes were reported and minor complaints were limited to neck muscle soreness that resolved within a few days. Ewing et al.[30] subjected human volunteers to simulated side impacts with acceleration levels greater than associated with the subject incident. No physical complaints were reported in response to these tests. Further work by Ewing et al.,[31] subjected human volunteers to over one hundred simulated side impacts with acceleration levels greater than those associated with the subject incident. Again, no physical complaints were reported in response to these tests. Fugger et al.[32] conducted lateral impact tests involving human volunteers. The acceleration levels again exceeded that associated with the subject incident. Physical complaints immediately after impact were noted following only five of the tests. These complaints were transient in nature and consisted of back pain, and slight headache that lasted only a few minutes. All of the complaints came following the higher energy impacts. Bailey et al.[33] conducted lateral impact tests with human volunteers. Acceleration levels were greater than associated with the subject incident, and no physical symptoms were reported in response to these tests. Restrained human volunteers have also been regularly and repeatedly subjected to acceleration levels greater than that associated with the subject incident without acute lumbar or thoracic spine trauma.[34,35]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The accelerations created by the subject incident were well within the limits of human tolerance. For these reasons, a causal link between the subject incident and the thoracic and lumbosacral injuries claimed by Ms. Sams cannot be made.

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[28] Zaborowski, A.B., (1964) Human Tolerance to Lateral Impact with Lap Belt Only, (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

[29] Zaborowski, A.B., (1964) Lateral Impact Studies: Lap Belt Shoulder Harness Investigations, (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

[30] Ewing, C., Thomas, D., et al., (1977) Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration, (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

[31] Ewing, C., Thomas, D., et al., (1978) Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration, (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

[32] Fugger, T.F., et al., (2002) Human Occupant Kinematics in Low Speed Side Impacts, (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

[33] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[34] Eiband, A.M., (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

[35] Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On January 2, 2010, Ms. Jessica Sams was the restrained driver of a 2005 Honda Civic when the right rear side was contacted by a 1992-1996 Toyota Camry.
2. The contact between the two vehicles is consistent with lateral impact for the Honda.
3. The change in velocity was a nominal 5 miles per hour with peak accelerations less than 2.3g.
4. The acceleration experienced by Ms. Sams was within the limits of human tolerance and the personal tolerance levels of Ms. Sams based on an engineering analysis of Ms. Sams's physical activities and were comparable to that experienced during various daily activities.
5. If any of the crash forces were beyond the level of muscle reaction, it would have resulted in primarily rightward motion of Ms. Sams's body relative to the interior of the vehicle. Any motion would have been well within the normal range of motion and tolerance levels of Ms. Sams and the protection afforded by the available restraint system.
6. There is no injury mechanism present in the subject incident to account for Ms. Sams's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
7. There is no injury mechanism present in the subject incident to account for Ms. Sams's claimed thoracic and lumbosacral injuries. As such, a causal relationship between the subject incident and the thoracic and lumbosacral injuries cannot be made.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer
BWP/llr

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August 20, 2012

Melinda Wieder, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Lee, Justin v. Carol Jean Kirner*
File No.: 534837144008
ARCCA Case No.: 2107-643

Dear Ms. Wieder:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Justin Lee. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the State of Washington Police Traffic Crash Report and other available documents, on August 25, 2010, Mr. Justin Lee was the restrained driver of a 2000 Toyota 4Runner traveling southbound on S Cedar Street in Port Angeles, Washington. Mr. Stan Myers was the restrained right front passenger in the 2000 Toyota 4Runner. Ms. Carol Kirner was the restrained driver of a 2005 Subaru Forester traveling westbound along W 8th Street perpendicular to the Toyota. According to the available documents, the Subaru veered to the right resulting in a sideswipe collision with the Toyota. As a result, the right side of the incident Subaru contacted the front of the subject Toyota. No airbags were deployed as a result of the impact, and the Subaru was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Crash Report, Report No. 2986010
- Nine (9) color photographic reproductions of the subject 2000 Toyota 4Runner
- Sixteen (16) color photographic reproductions of the incident 2005 Subaru Forester
- Evergreen Collision Center repair estimate for the subject 2000 Toyota 4Runner [November 8, 2010]
- Evergreen Collision Center Supplement of Record 1 with Summary for the incident 2005 Subaru Forester [September 22, 2010]
- Recorded Statement Transcript of Kathleen Delgado [October 5, 2010]
- Recorded Statement Transcript of Carol Jean Kirner [September 13, 2010]
- Recorded Statement Transcript of Justin Lee [September 30, 2010]
- VinLink data sheet for the subject 2000 Toyota 4Runner
- Expert AutoStats data sheets for a 2000 Toyota 4Runner
- VinLink data sheet for the incident 2005 Subaru Forester
- Expert AutoStats data sheets for a 2005 Subaru Forester

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota 4Runner and incident Subaru Forester in association with accepted engineering methodologies. According to the available documents, the subject incident was a sideswipe impact between the Toyota 4Runner and the Subaru Forester, where the primary points of impact to the incident Subaru and the subject Toyota were to the right side and front, respectively.

The damage estimate of the subject Toyota 4Runner indicated damage primarily to the front bumper valance, face bar, and front bumper plate; which is consistent with the photographic reproductions of the subject Toyota (Figure 1). The damage estimate of the incident Subaru Forester indicated damage primarily to the front bumper cover, right headlamp assembly, right fender, right fender extension, right fender liner, right lower frame, right side wheels, right control arm, right axle assembly, right inner tie rod, right outer tie rod, right front door shell, right molding assembly, right mirror assembly, right rear door shell, right quarter panel, right quarter glass, and rear bumper cover; which is consistent with the photographic reproductions of the incident Subaru (Figure 2). Note: all the damage to the incident Subaru is not due to contact with the subject Toyota. After contacting the subject Toyota the Subaru continued to strike a curb.

Figure 1: Reproductions of the subject 2000 Toyota 4Runner

Figure 2: Reproductions of the incident 2005 Subaru Forester

Scientific analyses of the photographs, itemized repair records, geometric measurements of the vehicles, and testimony identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[6] The laws of physics dictate that the lateral force exerted to the subject Toyota 4Runner was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the subject Toyota as a result of the sideswipe event was less than 1.9g.[7] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[8] the Delta-V associated with 1.9g of peak acceleration is 4.1 mph. Therefore, the subject Toyota in which Mr. Lee and Mr. Myers were seated during the sideswipe event was exposed to a lateral Delta-V of less than 4.1 mph with a peak lateral acceleration less than 1.9g.

The acceleration experienced due to gravity is 1g. This means that Mr. Lee and Mr. Myers experience 1g of loading while in a sedentary state. Therefore, Mr. Lee and Mr. Myers experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Lee and Mr. Myers in their daily lives would have increased the loading to their bodies beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual’s body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[9] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of

[6] Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[7] Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

[8] Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts, (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

[9] Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

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daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[10]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota 4Runner in which Mr. Myers and Mr. Lee were seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Myers or Mr. Lee in the subject incident.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On August 25, 2010, Mr. Justin Lee was the belted driver of a 2000 Toyota 4Runner that was contacted in the front in a sideswipe impact at low speed. Mr. Stan Myers was the belted right front passenger in the 2000 Toyota 4Runner.
2. The severity of the subject incident was consistent with a Delta-V less than 4.1 miles-per-hour with peak acceleration less than 1.9g for the subject 2000 Toyota 4Runner in which Mr. Lee and Mr. Myers were seated.
3. The acceleration experienced by Mr. Lee and Mr. Myers were within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

[10] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

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EXHIBIT
Probst 22
5-23-17

August 24, 2012

Dylan Becker, Esquire
Barger Law Group, PC
4949 Meadows Road, Suite 620
Lake Oswego, OR 97035

Re: *Green, Valenna v. Gabriela Warren*
ARCCA Case No.: 4202-006

Dear Mr. Becker:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Valenna Green. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

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inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on June 25, 2009, Ms. Valenna Green was the driver of a 1992 Saturn SL2 traveling westbound on NE 78th Street at the intersection with NE 72nd Avenue in Walnut Grove, Washington. Ms. Gabriela Warren was the driver of a 1997-2003 model Ford Escort traveling westbound on NE 78th Street directly behind the Saturn. According to the available documents, the Saturn was stopped preparing to turn left and was struck from behind by the Ford. As a result, the front of the incident Ford contacted the rear of the subject Saturn. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nineteen (19) color photographic reproductions of the subject 1992 Saturn SL2
- Four (4) color photographic reproductions of the incident 1997-2003 Ford Escort
- Geico Supplement of Record 1 with Summary for the subject 1992 Saturn SL2 [July 10, 2009]
- Complaint, *Valenna Green v. Gabriela Warren* [January 19, 2011]
- Deposition of Valenna Green [July 19, 2011]
- VinLink data sheet for the subject 1992 Saturn SL2
- Expert AutoStats data sheets for a 1992 Saturn SL2
- Expert AutoStats data sheets for a 1993 Saturn SL2
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1993 Saturn SL2
- Expert AutoStats data sheets for a 1997 Ford Escort
- Expert AutoStats data sheets for a 2003 Ford Escort
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1997 Ford Escort

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Saturn SL2 and incident Ford Escort in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Saturn SL2 and the Ford Escort, where the primary points of impact to the incident Ford and the subject Saturn were to the front and rear, respectively.

The damage estimate of the subject Saturn SL2 indicated damage primarily to the rear bumper cover and right trunk filler panel; which is consistent with the photographic reproductions of the subject Saturn (Figure 1). Note: the repair estimate for the subject Saturn indicates there was prior damage to the trunk lid area. The reviewed photographic reproductions of the incident Ford depict damage to the front bumper cover and license bracket area (Figure 2).

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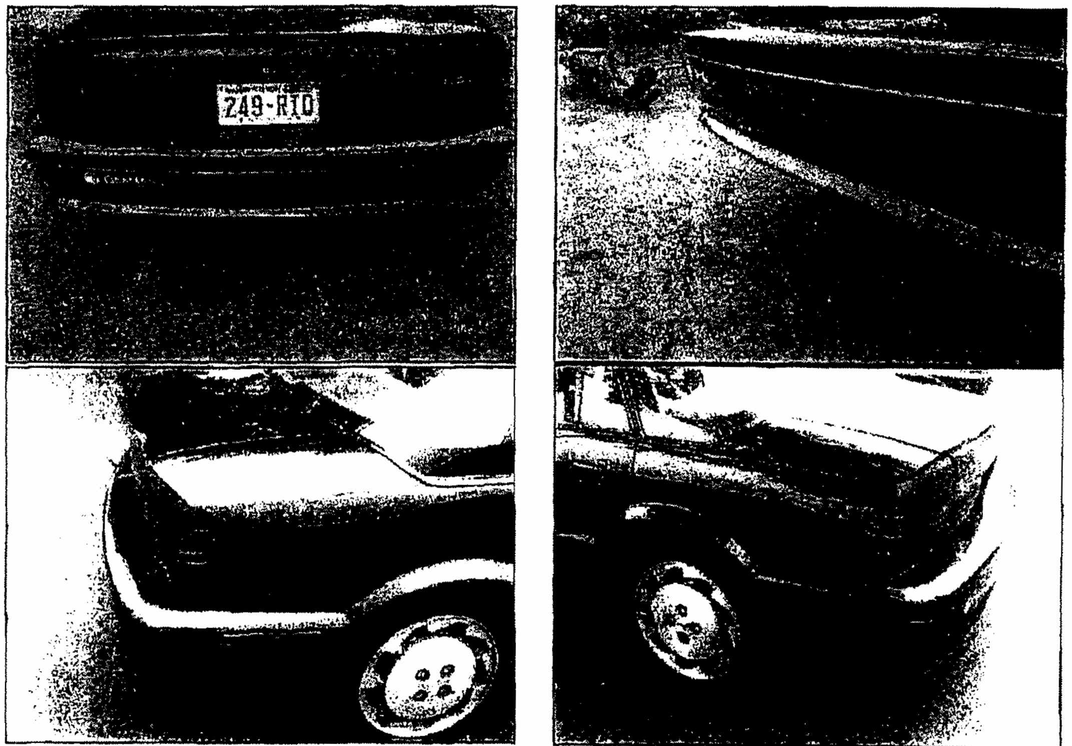

Figure 1: Reproductions of the subject 1992 Saturn SL2

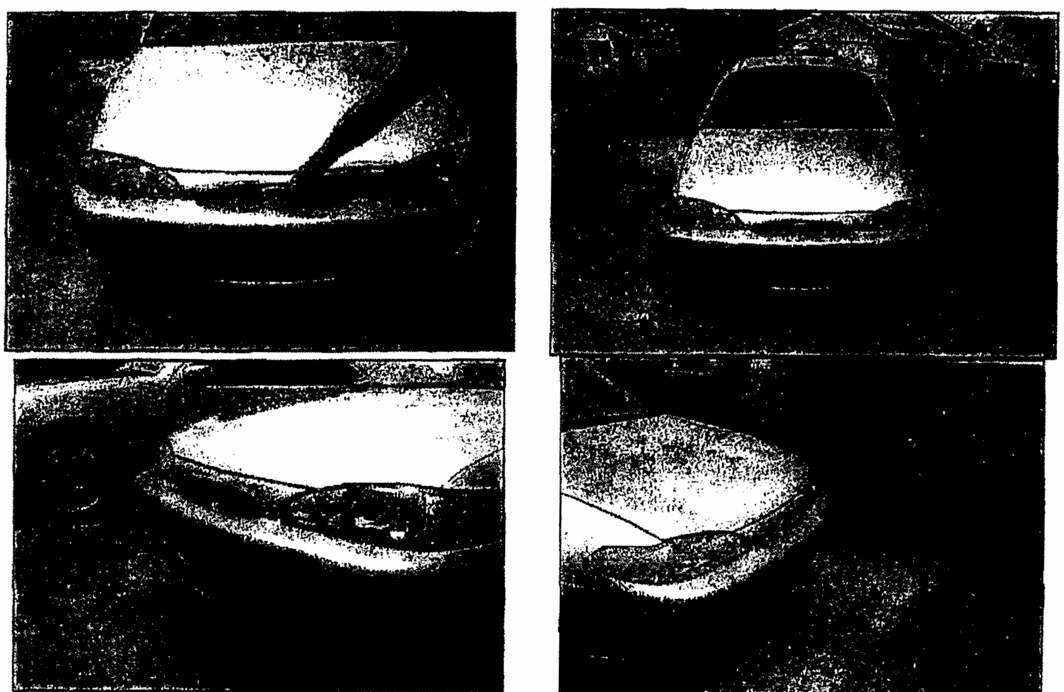

Figure 2: Reproductions of the incident 1997-2003 Ford Escort

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Saturn SL2, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[6] The IIHS tested a 1993 Saturn SL2, essentially the same vehicle as a 1992 Saturn SL2, in a five mile-per-hour rear impact into a flat barrier. The test Saturn sustained damage to the rear bumper absorber. The primary damage to the subject Saturn was to the rear bumper cover and right trunk filler panel. Thus, because the test Saturn in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1992 Saturn SL2.[7,8,9,10,11,12,13]

The IIHS tested a 1997 Ford Escort in a five mile-per-hour frontal impact into a flat barrier. The test Ford sustained deformation to the bumper bar, radiator support and left and right inner fender assemblies. While a repair estimate for the incident Ford was not available, the reviewed photographs did not indicate any deformation to the above mentioned components. Thus, because the test Ford in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is comparable if not greater to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1997 Ford Escort, essentially that same vehicle as all model year 1997 through 2003 Ford Escorts.[14,15,16,17,18,19,20]

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6 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

7 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

9 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

10 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

11 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

12 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

13 Insurance Institute for Highway Safety Low-Speed Crash Tests (1997). 1997 Ford Escort, Arlington, VA. Insurance Institute for Highway Safety.

14 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

17 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

18 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Insurance Institute for Highway Safety Low-Speed Crash Tests (1997). 1997 Ford Escort, Arlington, VA. Insurance Institute for Highway Safety.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Saturn SL2. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[21] By the laws of physics, the average acceleration experienced by the subject Saturn in which Ms. Green was seated was comparable to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Green experiences 1g of loading while in a sedentary state. Therefore, Ms. Green experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Green in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[22] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[23] Ms. Green was noted to be a infant teacher/employee of a child care center. This would entail bending and other movements, sitting in chairs, and potentially lifting substantial objects that would exceed the range of motion and/or forces of the subject incident.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Saturn SL2 in which Ms. Green was seated was well within the limits of human tolerance. West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[24] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[25] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean

21 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

22 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

23 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

24 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

25 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

accelerations between 1.8g and 2.6g, without sustaining any severe cervical, thoracic, or lumbar injuries.[26] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[27] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Green in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[28,29]

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On June 25, 2009, Ms. Valenna Green was the driver of a 1992 Saturn SL2 that was contacted in the rear at low speed by a 1997-2003 model Ford Escort.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with average acceleration comparable to 1.5g for the subject 1992 Saturn SL2 in which Ms. Green was seated.
3. The acceleration experienced by Ms. Green was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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26 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

27 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

28 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation*, 42:25-30.

29 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

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September 6, 2012

Judy Heit, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re: *Dahl, Keri vs. James Ashmore*
Claim No.: 154161734020
ARCCA Case No.: 3271-181

Dear Ms. Heit:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Keri Dahl. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On July 3, 2010, Ms. Keri Dahl was the restrained right front passenger of a 2003 Audi A6 traveling on 224th Street near Bothell, Washington. Mr. James Ashmore was the driver of a 2003 Toyota Highlander traveling on 224th Street directly behind the Audi A6. According to the available documents, the Audi was stopped for traffic and struck from behind by the incident Toyota. As a result, the front bumper of the incident Toyota contacted the rear of the subject Audi. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eighteen (18) color photographic reproductions of the subject 2003 Audi A6
- Twelve (12) color photographic reproductions of the incident 2003 Toyota Highlander
- Barrett's Collision County Line repair estimate for the subject 2003 Audi A6 [July 13, 2010]
- Barrett's Collision County Line Supplement of Record 1 with Summary for the subject 2003 Audi A6 [July 20, 2010]
- Deposition Transcript of Keri Dahl [April 26, 2012]
- Medical Records pertaining to Keri Dahl
- VinLink data sheet for the subject 2003 Audi A6
- Expert AutoStats data sheets for a 2003 Audi A6
- Expert AutoStats data sheets for a 1999 Audi A6
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 1999 Audi A6
- VinLink data sheet for the incident 2003 Toyota Highlander
- Expert AutoStats data sheets for a 2003 Toyota Highlander

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Ms. Dahl claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Dahl was occupying;
3. Determine Ms. Dahl's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Dahl's response to the subject incident;
5. Evaluate Ms. Dahl's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Dahl has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Head Injury
  - Concussion

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Audi A6 and incident Toyota Highlander in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Audi and the Toyota, where the primary points of impact to the incident Toyota and the subject Audi were to the front and rear, respectively.

The damage estimate of the subject Audi indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). The reviewed photographic reproductions of the incident Toyota depicted damage to the license plate and license plate holder (Figure 2).

Figure 1: Reproductions of photographs of the subject 2003 Audi A6

Figure 2: Reproductions of photographs of the incident 2003 Toyota Highlander

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Audi A6 and geometric measurements of a 2003 Audi A6 revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of an Audi A6 would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 6.5 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Audi indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the Insurance Institute for Highway Safety (IIHS) tested a 1999 Audi A6, essentially the same vehicle as the subject 2003 Audi A6, in a five mile-per-hour rear impact into a flat barrier which resulted in slightly more damage than the subject incident.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour and more consistent with 5 miles-per-hour for the subject Audi A6. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

associated with a 10 mile-per-hour and 5 mile-per-hour impact is 3.0g and 1.5g.[18] By the laws of physics, the average acceleration experienced by the subject Audi in which Ms. Dahl was seated was less than 3.0g and closer to 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Dahl experiences 1g of loading while in a sedentary state. Therefore, Ms. Dahl experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Dahl in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Dahl testified that prior to the subject incident she would create clay models, perform needlework, paint, cook, clean and ride a bicycle. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Audi in which Ms. Dahl was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Dahl's claimed injuries in the subject incident.

Kinematic Analysis:

Ms. Dahl testified that she was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Dahl's principle direction of motion would be rearward, relative to the subject vehicle. Additionally, Ms. Dahl testified that her body was turned sideways facing the driver at the time of the subject incident.

The laws of physics dictate that when the incident Toyota contacted the rear of the subject Audi, had there been enough energy transferred to initiate motion, the Audi would have been pushed forward causing Ms. Dahl's seat to move forward relative to her body, which would result in Ms. Dahl moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Dahl and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by

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18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Dahl would have been limited to well within the range of normal physiological limits.

Findings:

1. On July 3, 2010, Ms. Keri Dahl was the belted right front passenger of a 2003 Audi A6 that was contacted in the rear at low speed by a 2003 Toyota Highlander.
2. The change in velocity was less than 10 miles-per-hour and closer to 5 miles-per-hour with average accelerations less than 3.0g and closer to 1.5g.
3. The acceleration experienced by Ms. Dahl was within the limits of human tolerance, the personal tolerance levels of Ms. Dahl and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Dahl was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers

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22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Dahl was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Audi would be pushed forward and Ms. Dahl would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a “whiplash” injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2002 Audi A6, essentially the same vehicle as a 2003 Audi A6, showed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.25 inches in the “full down” position and 34.0 inches in the “full up” position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Dahl’s age (34 years), height (66 inches) and weight (180 lbs), Ms. Dahl has a normal seated height of 33.6 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Dahl and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury

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26 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

27 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Dahl in the subject incident. The subject incident had an average acceleration of a less than 3.0g and closer to 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. Dahl would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Dahl cannot be made.

Thoracic Spine

According to the available documents, Ms. Dahl was diagnosed with a thoracic sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

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29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 3.0g and closer to 1.5g. Ms. Dahl's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Dahl a causal link between the subject incident and claimed thoracic injuries cannot be made.

Concussion

Following the subject incident, Ms. Dahl was reported to have sustained a concussion. There was no reported loss of consciousness and Ms. Dahl testified that she did not strike the interior of the subject vehicle.

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34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

36 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3):184-191.

40 Schibye, B., Sogaard, K., et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

A brain injury without skull fracture is classified as a mild diffuse brain injury or concussion.[44,45] Acute onset of concussion requires that the brain tissue be stretched and/or strained beyond physiological limits.[46,47,48,49] The injury mechanism required to cause a concussion is loading to the brain that causes stretching and/or straining of the brain tissue beyond physiological limits. These injuries are associated with substantial impulsive or impact loads applied to the head.[50]

The subject incident lacked the energy necessary to cause Ms. Dahl's diagnosed concussion.[51,52] As described previously, had the loads associated with the subject incident been sufficient to overcome Ms. Dahl's muscle reaction forces, her body would have moved rearward relative to the Audi's interior. The seatback structure and three-point restraint that Ms. Dahl testified she was wearing would have limited her body motion. During this response, Ms. Dahl's head would have been subjected to some degree of rearward extension upon impact and potential head contact with the headrest. However this possible head contact would not have generated enough energy to cause injury or trauma to the head. [53]

This subject incident had an average acceleration less than 3.0g and closer to 1.5g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[54,55] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature, the subject incident created accelerations that were well within human tolerance and were comparable to accelerations applied during daily activities. Therefore, the subject incident was within Ms. Dahl's personal tolerance. In addition, the loads associated with the subject incident were not applied in the proper manner or with sufficient magnitude to generate the injury mechanism necessary for her diagnosed brain injury. As this crash event did not apply loads of sufficient magnitude to exceed Ms. Dahl's personal tolerance and the necessary injury mechanism

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44 Gennarelli, T.A., (1982) "Impact Injury Caused by Linear Acceleration: Mechanisms, Prevention, and Cost." NATO AGARD Conference 1-9.
45 Viano, D.C. Biomechanics of Head Injury – Toward a Theory Linking Head Dynamic Motion, Brain Tissue Deformation and Neural Trauma, (SAE 881708). Warrendale, PA. Society of Automotive Engineers.
46 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.
47 Gennarelli, T.A., (2003) "Mechanisms of Brain Injury." Journal of Emergency Medicine 11: 5-11.
48 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma,* 66(2):309-315.
49 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma,* 12(4):621-625.
50 Goldsmith, W., (2001) "The State of Head Injury Biomechanics: Past, Present, and Future: Part 1." Critical Reviews in Biomedical Engineering 29 (5 & 6): 441-600.
51 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma,* 66(2):309-315.
52 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma,* 12(4):621-625.
53 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.
54 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.
55 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

was not created, causation between the subject incident and her diagnosed concussion cannot be established.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 3, 2010, Ms. Keri Dahl was the belted right front passenger of a 2003 Audi A6 that was contacted in the rear at low speed by a 2003 Toyota Highlander.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour and closer to 5 miles-per-hour with an average acceleration less than 3.0g and closer to 1.5g for the subject 2003 Audi A6 in which Ms. Dahl was seated.
3. The acceleration experienced by Ms. Dahl was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Dahl's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Dahl's claimed cervical spine injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Dahl's claimed thoracic spine injuries. As such, a causal relationship between the subject incident and the thoracic injuries cannot be made.
7. There is no injury mechanism present in the subject incident to account for Ms. Dahl's claimed concussion. As such, a causal relationship between the subject incident and the concussion cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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EXHIBIT
Probst 23
5-23-17

September 11, 2012

Judy Heit, Esquire
Law Offices of Kelley J. Sweeney
1191 Second Avenue, Suite 500
Seattle, WA 98101

Re: *Brumfield, Christopher v. Ximena Bustamante*
Claim No.: 9354 5614 4008
ARCCA Case No.: 3271-165

Dear Ms. Heit:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Christopher Brumfield. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automot ngineers.

4 King, A.I., (2000) "Fundamentals of Impact B echanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On August 27, 2010, Mr. Christopher Brumfield was the restrained driver of a 1995 Honda Civic traveling eastbound on NE 55th Street near 25th Avenue NE in Seattle, Washington. Ms. Ximena Bustamante was the restrained driver of a 2002 Subaru Outback traveling on NE 55th Street directly behind the Honda. According to the available documents, the Honda was stopped for traffic and was struck from behind by the incident Subaru. As a result, the front bumper of the incident Subaru contacted the rear of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Thirty-four (34) color photographic reproductions of the subject 1995 Honda Civic
- Ten (10) color photographic reproductions of the subject 2002 Subaru Outback
- First National Insurance Company of America repair estimate for the subject 1995 Honda Civic [August 30, 2010]
- FutureForensics Investigation Report by Mark E. Olson [January 20, 2010]
- First National Insurance Company of America repair estimate for the incident 2002 Subaru Outback [August 30, 2010]
- Recorded Statement Transcript of Ximena Bustamante [August 27, 2010]
- Recorded Statement Transcript of Christopher Brumfield [October 13, 2010]
- Deposition Transcript of Christopher Brumfield [June 5, 2012]
- Medical Records pertaining to Christopher Brumfield
- VinLink data sheet for the subject 1995 Honda Civic
- Expert AutoStats data sheets for a 1995 Honda Civic
- VinLink data sheet for the incident 2002 Subaru Outback
- Expert AutoStats data sheets for a 2002 Subaru Outback
- Expert AutoStats data sheets for a 2000 Subaru Legacy
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2000 Subaru Legacy

ARCCA

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Brumfield claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Brumfield was occupying;
3. Determine Mr. Brumfield's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Brumfield's response to the subject incident.
5. Evaluate Mr. Brumfield's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Brumfield has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar and Sacroiliac Spine
  - Sprain/strain
  - L5-S1 right posterior central disc extrusion

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Civic and incident Subaru Outback in association with accepted engineering methodologies. According to the available documents, the subject incident

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

was a rear impact between the Honda and the Subaru, where the primary points of impact to the incident Subaru and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda Civic indicated damage primarily to the rear bumper cover, rear bumper reinforcement, energy absorber, trunk lid and rear end unibody; which is consistent with the reviewed photographic reproductions (Figure 1). The damage estimate of the incident Subaru Outback indicated damage primarily to the front bumper cover; which is consistent with the reviewed photographic reproductions (Figure 2).

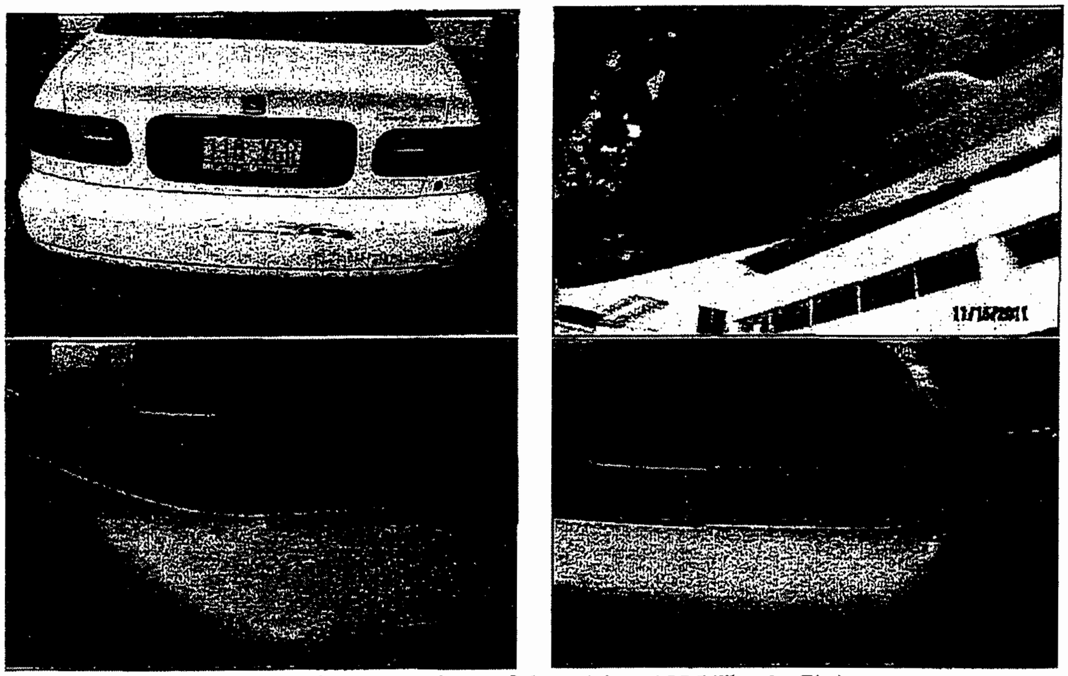

Figure 1: Reproductions of the subject 1995 Honda Civic

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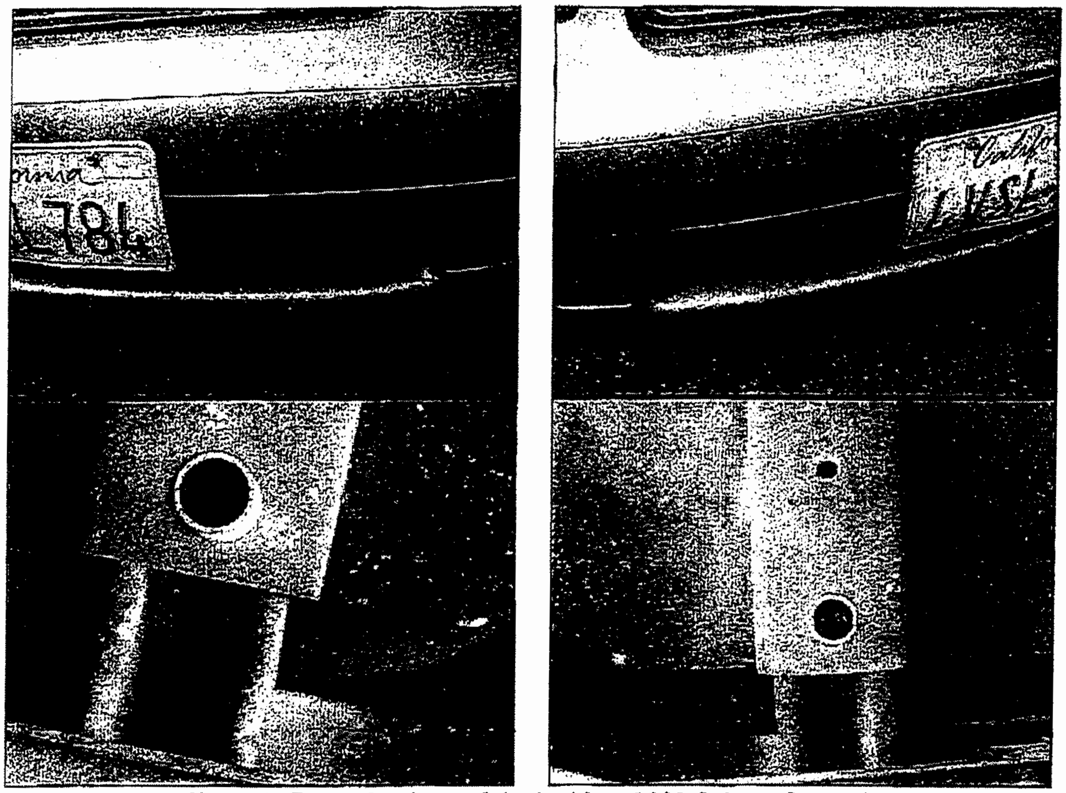

Figure 2: Reproductions of the incident 2002 Subaru Outback

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Subaru can be used to resolve the loads sustained by the subject Honda. That is, the forces sustained by the incident Subaru are equal and opposite to those of the subject Honda.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Subaru Outback, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2000 Subaru Legacy, essentially the same vehicle as a 2002 Subaru Outback, in a five mile-per-hour frontal impact into a flat barrier. The test Subaru sustained damage to the front bumper reinforcement, and the left and right front frame sidemember reinforcements. The primary damage to the incident Subaru was to the front bumper cover. Thus, because the test Subaru in the IIHS frontal impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident

[11] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 1995 Honda Civic.[12,13,14,15,16,17]

Review of the vehicle damage, incident data, published literature, engineering analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V of less than 7.7 miles-per-hour for the subject Honda Civic. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 7.7 mile-per-hour impact is 2.3g.[18] By the laws of physics, the average acceleration experienced by the subject Honda in which Mr. Brumfield was seated was less than 2.3g.

The acceleration experienced due to gravity is 1g. This means that Mr. Brumfield experiences 1g of loading while in a sedentary state. Therefore, Mr. Brumfield experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Brumfield in his daily life would have increased the loading to his body beyond the sedentary 1g. According to his testimony, prior to the subject incident Mr. Brumfield participated in hiking, lifting weights, running, backpacking, snowboarding, and biking. Additionally, Mr. Brumfield testified that he was working as an insurance agent, as well as operating his own repair and remodeling business. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which Mr. Brumfield was seated was well within the limits of human

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12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Brumfield's claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Brumfield was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Brumfield's principle direction of motion would be rearward, relative to his vehicle. Additionally, Mr. Brumfield testified that he was leaning forward to pick up a pen and was unaware of the impending impact. He testified that his body was pushed back into the seat as of result of the impact.

The laws of physics dictate that when the incident Subaru contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing Mr. Brumfield's seat to move forward relative to his body, which would result in Mr. Brumfield moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Brumfield and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Brumfield would have been limited to well within the range of normal physiological limits.

Findings:

1. On August 27, 2010, Mr. Christopher Brumfield was the belted driver of a 1995 Honda Civic that was contacted in the rear at low speed by a 2002 Subaru Outback.
2. The change in velocity was less than 7.7 miles-per-hour with average accelerations less than 2.3g.
3. The acceleration experienced by Mr. Brumfield was within the limits of human tolerance, the personal tolerance levels of Mr. Brumfield and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Brumfield was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[26]

Cervical Spine

According to the available documents, Mr. Brumfield was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and Mr. Brumfield would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

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24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

26 White III, A.A. and M.M. Panjabi, (1990) <u>Clinical Biomechanics of the Spine</u>. Philadelphia, J.B. Lippincott Company.

Examination of an exemplar 1994 Honda Civic, essentially the same vehicle as a 1995 Honda Civic, showed that the nominal height of the highback driver's seat with an unoccupied, uncompressed seat is 32.75 inches. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Brumfield's age (28 years), height (75 inches) and weight (230 lbs), Mr. Brumfield would have a normal seated height of 36.9 inches. Thus the seat is tall enough to have prevented hyperextension of Mr. Brumfield and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Brumfield in the subject incident. The subject incident had an average acceleration less than 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Mr. Brumfield would not have been exposed to any loading or motion outside of his personal tolerance levels.

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27 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

28 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

30 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

31 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

32 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Mr. Brumfield cannot be made.

Thoracic, Lumbar and Sacroiliac Spine

According to a lumbar MRI date February 28, 2011, there were findings consistent with a L5-S1 right posterior central disc extrusion with mass effect on the right S1 and S2 nerve roots. Additionally, the other available documents indicate Mr. Brumfield was diagnosed with a thoracic and sacroiliac sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the

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33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

34 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

35 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects," Accident Reconstruction Journal.

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Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 2.3g. Mr. Brumfield's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Brumfield, a causal link between the subject incident and claimed thoracic, lumbar and sacroiliac injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On August 27, 2010, Mr. Christopher Brumfield was the belted driver of a 1995 Honda Civic that was contacted in the rear at low speed by a 2002 Subaru Outback.

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36 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

39 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

40 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

41 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

42 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

43 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

44 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

2. The severity of the subject incident was consistent with a Delta-V less than 7.7 miles-per-hour with an average acceleration less than 2.3g for the subject 1995 Honda Civic in which Mr. Brumfield was seated.
3. The acceleration experienced by Mr. Brumfield was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Brumfield's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Mr. Brumfield's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Mr. Brumfield's claimed thoracic, lumbar and sacroiliac spine injuries. As such, a causal relationship between the subject incident and the thoracic, lumbar and sacroiliac injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call. This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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OCT 16 2012
Law Offices of
Kelley J. Sweeney

September 20, 2012

Mario Cava, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Allegue, Amber v. Ryan & Amy Miller*
Claim No.: 275819054036
ARCCA Case No.: 2107-653

Dear Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failure involved in the incident of Amber Allegue and Ivan Dunken. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

Incident Description:

According to the available documents, on December 9, 2010, Ms. Amber Allegue was the driver of a 2006 Honda Ridgeline traveling southbound on Highway 169 in Maple Valley, Washington. Mr. Ivan Dunken was the restrained right front passenger of the 2006 Honda Ridgeline. Ms. Amy Miller was the driver of a 2002 Volkswagen Cabrio traveling on Highway 169 directly behind the Honda. According to the available documents, the Honda was stopped for traffic and was struck from behind by the incident Volkswagen. As a result, the front of the incident Volkswagen contacted the rear of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 2006 Honda Ridgeline
- Five (5) color photographic reproductions of the incident 2002 Volkswagen Cabrio
- Safeco Insurance Company of Illinois repair estimate for the subject 2006 Honda Ridgeline [December 22, 2010]
- Safeco Insurance Company of Illinois repair estimate for the incident 2002 Volkswagen Cabrio [December 17, 2010]
- Recorded Statement Transcript of Amber Allegue [December 14, 2010]
- Medical Records pertaining to Amber Allegue
- Medical Records pertaining to Ivan Dunken
- VinLink data sheet for the subject 2006 Honda Ridgeline
- Expert AutoStats data sheets for a 2006 Honda Ridgeline
- VinLink data sheet for the incident 2002 Volkswagen Cabrio
- Expert AutoStats data sheets for a 2002 Volkswagen Cabrio

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that the occupants claim were caused by the subject incident;

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle the occupants were occupying;
3. Determine the occupants' kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported injuries and determine whether the defined biomechanical failure mechanisms were created during the occupants' response to the subject incident.
5. Evaluate the occupants' personal tolerance in the context of their pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and their reported injuries.

If the subject incident created the biomechanical failure mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Allegue has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar and Lumbosacral Spine
  - Sprain/strain

According to the available documents, Mr. Dunken has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Multilevel disc bulges/protrusions
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Ridgeline and incident Volkswagen Cabrio in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Volkswagen, where the primary points of impact to the incident Volkswagen and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda Ridgeline indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). The damage estimate of the incident Volkswagen Cabrio indicated damage primarily to the front bumper cover and front bumper cover molding; which is consistent with the reviewed photographic reproductions (Figure 2).

ARCCA

Figure 1: Reproductions of the subject 2006 Honda Ridgeline

Figure 2: Reproductions of the incident 2002 Volkswagen Cabrio

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Volkswagen can be used to resolve the loads sustained by the subject Honda. That is, the forces sustained by the incident Volkswagen are equal and opposite to those of the subject Honda.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the repair estimate of the incident Volkswagen Cabrio and geometric measurements of a 2002 Volkswagen Cabrio revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Volkswagen Cabrio would result in significant and visibly noticeable crush across the entirety of the incident vehicle's front structure, with a residual crush of 4.75 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-

11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
16 EDCRASH, Engineering Dynamics Corp.

per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the front of the incident Volkswagen Cabrio indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the above analysis is consistent with several IIHS low-speed crash tests for similar makes and model years as the incident Volkswagen Cabrio.

Review of the vehicle damage, incident data, published literature, conservation of momentum, engineering analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V significantly below 5.9 miles-per-hour for the subject Honda Ridgeline. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5.9 mile-per-hour impact is 1.8g.[18] By the laws of physics, the average acceleration experienced by the subject Honda in which the occupants were seated was less than 1.8g.

The acceleration experienced due to gravity is 1g. This means that Ms. Allegue and Mr. Dunken experience 1g of loading while in a sedentary state. Therefore, the occupants experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Allegue and Mr. Dunken in their daily lives would have increased the loading to their body beyond the sedentary 1g. According to the available documents, prior to the subject incident Ms. Allegue worked 25-30 hours per week as a deli clerk and was capable of performing normal daily chores. According to the available documents, prior to the subject incident Mr. Dunken worked as state inspector. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which the occupants were seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for the occupants' claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Dunken was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle

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17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

reactions, the occupants' principle direction of motion would be rearward, relative to the subject vehicle. Additionally, Ms Allegue was facing right and Mr. Dunken was facing left at the time of the subject incident.

The laws of physics dictate that when the incident Volkswagen contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing the occupants' seat to move forward relative to their bodies, which would result in the occupants moving rearward relative to the interior of the subject vehicle. This interaction between the occupants and the subject vehicle's interior would cause their bodies to load into the seatback structures. Specifically, their torsos and pelvises would settle back into their respective seatbacks. The low accelerations resulting from this collision would have caused little, or no, forward rebound of their bodies away from the seat backs.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of the occupants would have been limited to well within the range of normal physiological limits.

Findings:

1. On December 9, 2010, Ms. Amber Allegue was the driver of a 2006 Honda Ridgeline that was contacted in the rear at low speed by a 2002 Volkswagen Cabrio. Mr. Ivan Dunken was the restrained right front passenger of the 2006 Honda Ridgeline.
2. The change in velocity was significantly below 5.9 miles-per-hour with average accelerations less than 1.8g.
3. The acceleration experienced by the occupants was within the limits of human tolerance, the personal tolerance levels of the occupants and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the occupants was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biological failure mechanism present to causally link their reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a known biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[26]

Cervical Spine

According to the available documents, Ms. Allegue and Mr. Dunken were diagnosed with a cervical sprain/strain. Additionally, a cervical MRI report of Mr. Dunken dated January 28, 2011, indicated there were findings consistent with a C4-5 shallow midline disc protrusion along with shallow midline disc bulges at the C3-4, C5-6 and C6-7 levels.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and the occupants would have moved rearward relative to the vehicle, until their motion was stopped by the seatbacks. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 Honda Ridgeline showed that the nominal height of the front seats with an unoccupied, uncompressed seat is 32.0 inches in the full down position and 34.5 inches in the full up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Allegue's age (31 years), height (60 inches) and weight (110 lbs), Ms. Allegue

[26] White III, A.A. and M.M. Panjabi, (1990) Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

would have a normal seated height of 31.0 inches. Based on an anthropometric regression of Mr. Dunken's age (49 years), height (68 inches) and weight (183 lbs), Mr. Dunken would have a normal seated height of 34.1 inches. Thus the seat is tall enough to have prevented hyperextension of the occupants and one would not expect to see any biomechanical failure that would exceed transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range acute, one would not expect acute, traumatic biomechanical failure to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by the occupants in the subject incident. The subject incident had an average acceleration less than 1.8g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] The occupants would not have been exposed to any loading or motion outside of their personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak

27 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

28 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

30 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

31 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

32 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

34 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/biomechanical failures. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of the occupants cannot be made.

Thoracic, Lumbar and Lumbosacral Spine

According to the available documents, Ms. Allegue and Mr. Dunken were diagnosed with a thoracic and lumbar sprain/strain. Additionally, Ms. Allegue was diagnosed with a lumbosacral sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic, lumbar and sacral spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic, lumbar and sacral spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 1.8g. The occupants' thoracic and lumbar spines would not have been exposed to any loading or motion outside

35 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

36 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

of the range of their personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of the occupants, a causal link between the subject incident and claimed thoracic, lumbar and lumbosacral biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, prior to the subject incident Ms. Allegue worked 25-30 hours per week as a deli clerk and was capable of performing normal daily chores. According to the available documents, prior to the subject incident Mr. Dunken worked as state inspector. In addition it was noted that after the subject incident Mr. Dunken was capable of "playing ball." These activities can produce greater movement, or stretch, to the soft tissues of Ms. Allegue and Mr. Dunken and produce comparable, if not greater, forces applied to the cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 9, 2010, Ms. Amber Allegue was the driver of a 2006 Honda Ridgeline that was contacted in the rear at low speed by a 2002 Volkswagen Cabrio. Mr. Ivan Dunken was the restrained right front passenger of the 2006 Honda Ridgeline.
2. The severity of the subject incident was consistent with a Delta-V significantly below 5.9 miles-per-hour with an average acceleration less than 1.8g for the subject 2006 Honda Ridgeline in which the occupants were seated.

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38 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

39 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

40 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3):184-191.

41 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

42 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

43 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

44 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

3. The acceleration experienced by the occupants was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupants' bodies back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical trauma cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed thoracic, lumbar and lumbosacral spine injuries. As such, a causal relationship between the subject incident and the thoracic, lumbar and lumbosacral trauma cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call. This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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EXHIBIT
PENGAD 800-631-6989
Probst 24
5-23-17 YMY

September 28, 2012

Mario Cava, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Nettles, Willard v. Rebecca Jo Sager*
Claim No.: 560162534008
ARCCA Case No.: 3271-206

Dear Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failure involved in the incident of Willard Nettles. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on June 14, 2010, Mr. Willard Nettles was the driver of a 1999 Dodge B1500 which was struck from behind by a vehicle driven by Rebecca Jo Sager.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nine (9) color photographic reproductions of the subject 1999 Dodge B1500
- Fourteen (14) grayscale photographic reproductions of the subject 1999 Dodge B1500
- Jacobus Carstar Preliminary estimate for the subject 1999 Dodge B1500 [July 6, 2010]
- Mackin's East Vancouver Auto Body repair estimate for the subject 1999 Dodge B1500 [June 17, 2010]
- First National Insurance Company of America Supplement of Record 1 with Summary for the subject 1999 Dodge B1500 [August 12, 2010]
- Medical Records pertaining to Willard Nettles
- VinLink data sheet for the subject 1999 Dodge B1500
- Expert AutoStats data sheets for a 1999 Dodge B1500

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Nettles claim were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Nettles was occupying;
3. Determine Mr. Nettles's kinematic response within the vehicle as a result of the subject incident;

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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4. Define the biomechanical failure mechanisms known to cause the reported injuries and determine whether the defined biomechanical failure mechanisms were created during Mr. Nettles's response to the subject incident.
5. Evaluate Mr. Nettles's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the biomechanical failure mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Nettles has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Dodge B1500 in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Dodge and the incident vehicle, where the primary points of impact to the incident vehicle and the subject Dodge were to the front and rear, respectively.

The damage estimate of the subject Dodge B1500 indicated damage primarily to the rear bumper and right side corner panel; which is consistent with the reviewed photographic reproductions (Figure 1).

Figure 1: Reproductions of photographs of the subject 1999 Dodge B1500

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the repair estimate of the subject Dodge B1500 and geometric measurements of a 2002 Dodge B1500 revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Dodge B1500 would result in significant and visibly noticeable crush across the entirety of the incident vehicle's rear structure, with a residual crush of 4.25 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Dodge B1500 indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the Insurance Institute for Highway Safety (IIHS) tested multiple Dodge vehicles including a 2002 Dodge Ram 1500, with a rear bumper design similar to the subject 2002 Dodge B1500, in a five mile-per-hour rear impact into a flat barrier which resulted in slightly more damage than the subject incident.

Review of the vehicle damage, incident data, published literature, conservation of momentum, engineering analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V significantly below 10 miles-per-hour for the subject Dodge B1500 and more consistent with a 5 mile-per-hour Delta-V. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the peak acceleration associated with a 10 mile-per-hour impact is 4.6g and 2.3 for 5 miles-per-hour.[18] By the laws of physics, the peak acceleration experienced by the subject Dodge in which Mr. Nettles was seated was less than 4.6g and more consistent with 2.3g.

The acceleration experienced due to gravity is 1g. This means that Mr. Nettles experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Nettles in his daily life would have increased the loading to his body beyond the sedentary 1g. According to the available documents, prior to the subject incident Mr. Nettles was capable of performing normal daily chores. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs,

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
16 EDCRASH, Engineering Dynamics Corp.
17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Dodge in which Mr. Nettles were seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Mr. Nettles claimed injuries in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. Nettles was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Nettles's principle direction of motion would be rearward, relative to the subject vehicle.

The laws of physics dictate that when the incident vehicle contacted the rear of the subject Dodge, had there been enough energy transferred to initiate motion, the Dodge would have been pushed forward causing the vehicle seat to move forward relative to Mr. Nettles, which would result in Mr. Nettles moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Nettles and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Nettles would have been limited to well within the range of normal physiological limits.

Findings:

1. On June 14, 2010, Mr. Willard Nettles was the driver of a 1999 Dodge B1500 that was contacted in the rear at low speed.

2. The change in velocity was significantly below 10 miles-per-hour and more consistent with 5 miles-per-hour with peak accelerations consistent with 2.3g.

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19 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

3. The acceleration experienced by Mr. Nettles was within the limits of human tolerance, the personal tolerance levels of Mr. Nettles and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Nettles was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biological failure mechanism present to causally link his reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a known biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Mr. Nettles was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Dodge would be pushed forward and Mr. Nettles would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the

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24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Nettles in the subject incident. The subject incident had a peak acceleration consistent with 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Mr. Nettles would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

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26 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

27 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism due to insufficient forces, a causal link between the subject incident and the reported cervical spine injuries of Mr. Nettles cannot be made.

Thoracic, and Lumbar Spine

According to the available documents, Mr. Nettles was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had a peak acceleration consistent with 2.3g. Mr. Nettles's thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of his personal

[34] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[35] Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[36] Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

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tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Nettles, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, prior to the subject incident Mr. Nettles worked around his house and performed yard work. He was also noted to perform activities that required bending, kneeling, lifting, and walking. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Nettles and produce comparable, if not greater, forces applied to the cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On June 14, 2010, Mr. Willard Nettles was the driver of a 1999 Dodge B1500 that was contacted in the rear at low speed
2. The severity of the subject incident was consistent with a Delta-V significantly below 10 miles-per-hour and more consistent with 5 miles-per-hour; with a peak acceleration consistent with 2.3g for the subject 1999 Dodge B1500 in which Mr. Nettles was seated.
3. The acceleration experienced by Mr. Nettles was within the limits of human tolerance and comparable to that experienced during various daily activities.

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37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Nettles's body back toward the seatback structure. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Nettles's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical trauma cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Nettles's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar trauma cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call. This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

069S361120556

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EXHIBIT
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5-23-17 VMY

October 4, 2012

Marie Dolack, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

RECEIVED
By
DEC 20 2012
Law Offices of
Kelley J. Sweeney

Re: *Ehringer, Wendy v. Leon & Linda Capelouto*
Claim No.: 145749473007
ARCCA Case No.: 3271-220

Dear Ms. Dolack:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Wendy Ehringer. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

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Incident Description:

According to the available documents, on July 25, 2008, Ms. Wendy Ehringer was the restrained driver of a 2002 Saab 9-3 traveling westbound on Fauntleroy Way SW in Seattle, Washington. Ms. Linda Capelouto was the driver of a 2004 Ford Thunderbird traveling on Fauntleroy Way SW directly behind the Saab. According to the available documents, the Saab was stopped preparing to turn right onto California Avenue SW and was struck from behind by the incident Ford. As a result, the front of the incident Ford contacted the rear of the subject Saab. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Seven (7) color photographic reproductions of the subject 2002 Saab 9-3
- Thirteen (13) color photographic reproductions of the incident 2004 Ford Thunderbird
- Thoroughbred Collision Center – West Seattle repair estimate for the subject 2002 Saab 9-3 [August 5, 2008]
- Thoroughbred Collision Center – West Seattle Supplement of Record 1 with Summary for the subject 2002 Saab 9-3 [August 15, 2008]
- Safeco Insurance Company of Illinois repair estimate for the incident 2004 Ford Thunderbird [September 1, 2011]
- Defendants' First Interrogatories and Requests for Production of Documents to Plaintiff with Responses and Objections Thereto, *Wendy Ehringer vs. Leon Capelouto and Linda Capelouto* [September 23, 2011]
- Defendants' First Interrogatories and Requests for Production of Documents to Plaintiff and First Supplemental Responses and Objections Thereto, *Wendy Ehringer vs. Leon Capelouto and Linda Capelouto* [October 12, 2011]
- Defendants' First Interrogatories and Requests for Production of Documents to Plaintiff and Second Supplemental Responses and Objections Thereto, *Wendy Ehringer vs. Leon Capelouto and Linda Capelouto* [February 8, 2012]
- Deposition Transcript of Wendy Ehringer [September 14, 2012]
- Medical Records pertaining to Wendy Ehringer
- VinLink data sheet for the subject 2002 Saab 9-3
- Expert AutoStats data sheets for a 2002 Saab 9-3
- VinLink data sheet for the incident 2004 Ford Thunderbird
- Expert AutoStats data sheets for a 2004 Ford Thunderbird

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. Ehringer claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Ehringer was occupying;
3. Determine Ms. Ehringer's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Ms. Ehringer's response to the subject incident.
5. Evaluate Ms. Ehringer's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Ehringer has reported the following injuries as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic and Lumbar Spine
    - Sprain/strain
- Right Shoulder
    - Supraspinatus and subscapularis tendon tears

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Saab 9-3 and incident Ford Thunderbird in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Saab and the Ford, where the primary points of impact to the incident Ford and the subject Saab were to the front and rear, respectively.

The damage estimate of the subject Saab 9-3 indicated damage primarily to the rear bumper assembly; which is consistent with the reviewed photographic reproductions (Figure 1). Ms. Ehringer testified she thinks she remembers imprints from the incident Ford's license plate in the rear bumper of the subject vehicle. The damage estimate of the incident Ford Thunderbird indicated damage primarily to

[7] Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

[10] Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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the front bumper cover and license bracket which is consistent with the reviewed photographic reproductions (Figure 2). Ms. Ehringer testified that she did not see any damage on the incident Ford

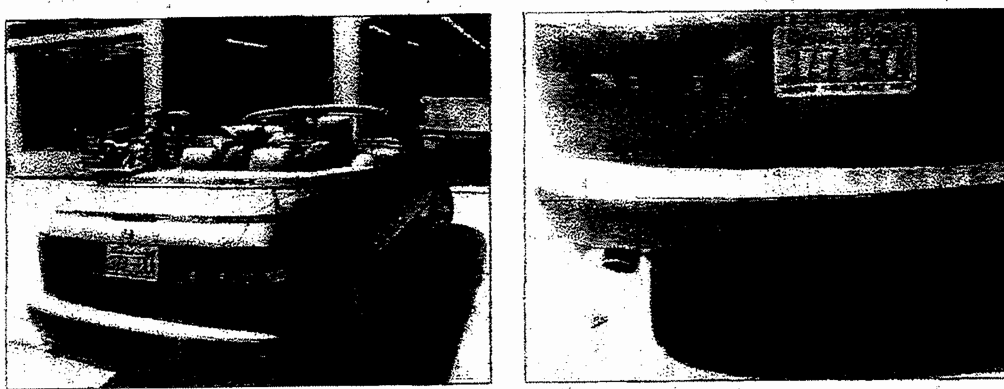

Figure 1: Reproductions of the subject 2002 Saab 9-3

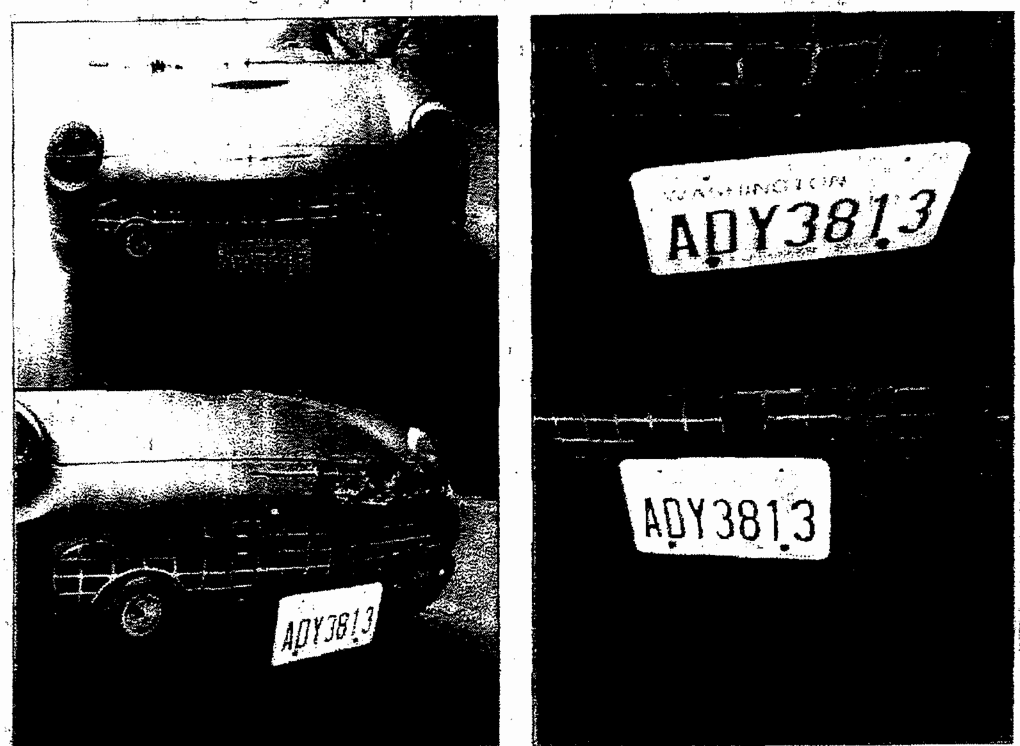

Figure 2: Reproductions of the incident 2004 Ford Thunderbird

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of

11 [illegible]
12 [illegible] and [illegible] Validation [illegible]

the subject Saab 9-3 and geometric measurements of a 2002 Saab 9-3 revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Saab 9-3 would result in significant and visibly noticeable crush across the entire rear of the subject vehicle's rear structure, with a residual crush of 5.25 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Saab 9-3 indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the Insurance Institute for Highway Safety (IIHS) tested multiple General Motors (Saab was a wholly owned subsidiary) and Ford vehicles from the era of the incident and subject vehicle with similar bumper designs, in a five mile-per-hour impact into a flat barrier which resulted in comparable damage.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour, and more consistent with 5 miles-per-hour, for the subject Saab 9-3. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the peak acceleration associated with an 10 mile-per-hour impact is 4.6g and 2.3g for 5 miles-per-hour.[18] By the laws of physics, the peak acceleration experienced by the subject Saab 9-3 in which Ms. Ehringer was seated was less than 4.6g and more consistent with 2.3g.

The acceleration experienced due to gravity is 1g. This means that Ms. Ehringer experiences 1g of loading while in a sedentary state. Therefore, Ms. Ehringer experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Ehringer in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, prior to the subject incident Ms. Ehringer was able to perform the household duties of cooking, cleaning, and groceries. Additionally, Ms. Ehringer testified that she participated in yoga and walking, along with working full time as a paralegal. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical, thoracic, and lumbar spine accelerations during activities of daily living such

[13] Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

[14] Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

[15] Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

[16] EDCRASH, Engineering Dynamics Corp.

[17] Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

[18] Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

[19] Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

as running, sitting quickly in chairs, and jumping are comparable to or greater than the peak acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Saab in which Ms. Ehringer was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Ms. Ehringer's claimed injuries in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. Ehringer was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Ehringer's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. Ehringer testified that she was aware of the impending impact and bracing with her right arm on the steering wheel.

The laws of physics dictate that when the incident Ford contacted the rear of the subject Saab, had there been enough energy transferred to initiate motion, the Saab would have been pushed forward causing Ms. Ehringer's seat to move forward relative to her body, which would result in Ms. Ehringer moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Ehringer and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Ehringer would have been limited to well within the range of normal physiological limits.

Findings:

1. On January 25, 2008, Ms. Wendy Ehringer was the restrained driver of a 2002 Saab 9-3 that was contacted in the rear at low speed by a 2004 Ford Thunderbird.
2. The change in velocity was less than 10 miles-per-hour, and consistent with 5 miles-per-hour, with peak accelerations less than 4.6g and consistent with 2.3g.
3. The acceleration experienced by Ms. Ehringer was within the limits of human tolerance, the personal tolerance levels of Ms. Ehringer and comparable to that experienced during various daily activities.

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20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Ehringer was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link her reported injuries and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Ehringer was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Saab 9-3 would be pushed forward and Ms. Ehringer would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2001 Saab 9-3, essentially the same vehicle as the subject vehicle, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 28.75 inches in the full down position and 32.25 inches in the full up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Ehringer's age (47 years), height

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[24] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[25] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

(63 inches) and weight (185 lbs), Ms. Ehringer has a normal seated height of 32.2 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Ehringer and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Ehringer in the subject incident. The subject incident had a peak acceleration less than 4.6g and more consistent with 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. Ehringer would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[28] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

[29] Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

[30] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation*, 42:25-30.

[31] Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

[32] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

[33] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injury of Ms. Ehringer cannot be made.

Thoracic and Lumbar Spine

According to the available documents, Ms. Ehringer was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic or lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had a peak acceleration less than 4.6g and more consistent with 2.3g. Ms. Ehringer's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that

[34] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[35] Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[36] Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[37] Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[38] Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[39] Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

[40] Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Ehringer, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

Right Shoulder

According to an operative report of Ms. Ehringer's right shoulder dated June 16, 2011, there were findings consistent with a full thickness tear of the supraspinatus involving the entire width of the tendon, significant compromise to the biceps anchor and a partial thickness tear of the subscapularis tendon.

There is no reason to assume that the claimed right shoulder injuries are causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Saab 9-3 would be pushed forward and Ms. Ehringer would have moved rearward relative to the vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of Ms. Ehringer's shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Ehringer's body away from the seatback.[44] Ms. Ehringer testified she was wearing the available three-point restraint, therefore any load acting on the shoulder area due to restraint forces would have been dispersed over Ms. Ehringer's left shoulder, torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the injury mechanisms necessary to cause shoulder trauma or injury to her right shoulder. The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Ehringer's right shoulder would have been limited to well within the range of normal physiological limits.

Injuries to the shoulder occur when an event consists of both the appropriate injury mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The two mechanisms for rotator cuff injury are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the shoulder joint.[45] The supraspinatus tendon is commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming. These mechanisms were not created in the subject collision. Repetitive microtrauma of the shoulder, the latter mechanism,

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41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

44 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

45 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins

is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

The subject incident had a peak acceleration level that was less than 4.6g and more consistent with 2.3g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder injuries were reported.[46,47,48,49,50] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[51,52,53,54] As a result, Ms. Ehringer's right shoulder would not have been exposed to any loading forces outside her personal tolerance range.

The subject incident lacks the appropriate injury mechanism to produce trauma to the right shoulder. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Ms. Ehringer would tend to move rearward relative to the subject vehicle. Ms. Ehringer testified she did not contact her right shoulder on any rigid interior object. There was no bruising, laceration, or abrasions associated with interaction of the vehicle interior in the subject incident. For these reasons, a causal link between the subject incident and the right shoulder injuries claimed by Ms. Ehringer cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 25, 2008, Ms. Wendy Ehringer was the restrained driver of a 2002 Saab 9-3 that was contacted in the rear at low speed by a 2004 Ford Thunderbird.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour and more consistent with 5-miles-per-hour with a peak acceleration less than 4.6g and more consistent with 2.3g for the subject 2002 Saab 9-3 in which Ms. Ehringer was seated.
3. The acceleration experienced by Ms. Ehringer was within the limits of human tolerance, her personal tolerance, and comparable to that experienced during various daily activities.

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46 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

48 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

49 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). Rear-end Impact Testing with Human Test Subjects (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

50 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

51 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

52 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

53 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

54 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Ehringer's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Ms. Ehringer's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injury cannot be made.
6. There is no injury mechanism present in the subject incident to account for Ms. Ehringer's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.
7. There is no injury mechanism present in the subject incident to account for Ms. Ehringer's claimed right shoulder injuries. As such, a causal relationship between the subject incident and the right shoulder injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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Sweeney

October 16, 2012

Mario Cava, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

EXHIBIT
Probst 26
5-23-17 YMY

Re: *Johnson, Yutta v. Max Harrison*
ARCCA Case No.: 3271-200

Dear Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Yutta Johnson. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on July 10, 2009, Ms. Yutta Johnson was the restrained driver of a 2009 Dodge Caliber traveling westbound on Wall Street in Everett, Washington. Mr. Max Harrison was the restrained driver of a 2004 Lexus ES330 exiting the Oakes alleyway southbound, perpendicular to the Dodge. According to the available documents, Mr. Harrison could not see the subject Dodge and continued along his path of travel exiting the alleyway resulting in a sideswipe collision. As a result, the front of the incident Lexus contacted the right side of the subject Dodge. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 3278578
- Seven (7) grayscale photographic reproductions of the subject 2009 Dodge Caliber
- Nine (9) color photographic reproductions of the incident 2004 Lexus ES330
- Avis Budget Group Supplement 2 for the subject 2009 Dodge Caliber [July 21, 2009]
- Central Body Works Inc. preliminary estimate for the incident 2004 Lexus ES330 [February 3, 2011]
- Settlement Demand [May 22, 2012]
- Recorded Statement Transcript of Max Harrison [July 14, 2009]
- Medical Records pertaining to Yutta Johnson
- VinLink data sheet for the subject 2009 Dodge Caliber
- Expert AutoStats data sheets for a 2009 Dodge Caliber
- VinLink data sheet for the incident 2004 Lexus ES330
- Expert AutoStats data sheets for a 2004 Lexus ES330

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the injuries that Ms. Johnson claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Johnson was occupying;
3. Determine Ms. Johnson's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported injuries and determine whether the defined biomechanical failure mechanisms were created during Ms. Johnson's response to the subject incident;
5. Evaluate Ms. Johnson's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and her reported injuries.

If the subject incident created the biomechanical failure mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Ms. Johnson has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Dodge Caliber and incident Lexus ES330 in association with accepted engineering methodologies. According to the available documents, the subject incident was a sideswipe impact between the Dodge Caliber and the Lexus ES330, where the primary points of impact to the incident Lexus and the subject Dodge were to the front and right side, respectively.

The damage estimate of the subject Dodge Caliber indicated damage primarily to the right fender and right front door panel; which is consistent with the photographic reproductions of the subject Dodge (Figure 1). The damage estimate of the incident Lexus ES330 indicated damage primarily to the front bumper cover and license bracket; which is consistent with the photographic reproductions of the incident Lexus (Figure 2).

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7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign. Human Kinetics.

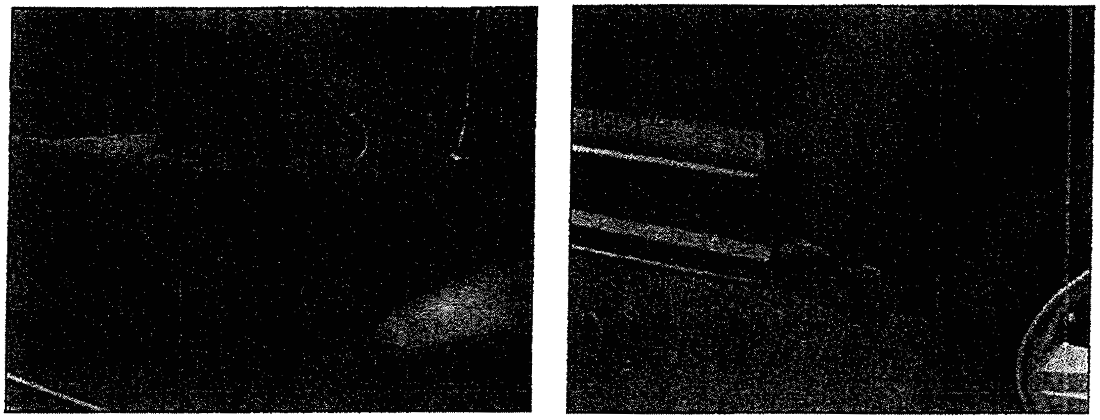

Figure 1: Reproductions of photographs of the subject 2009 Dodge Caliber

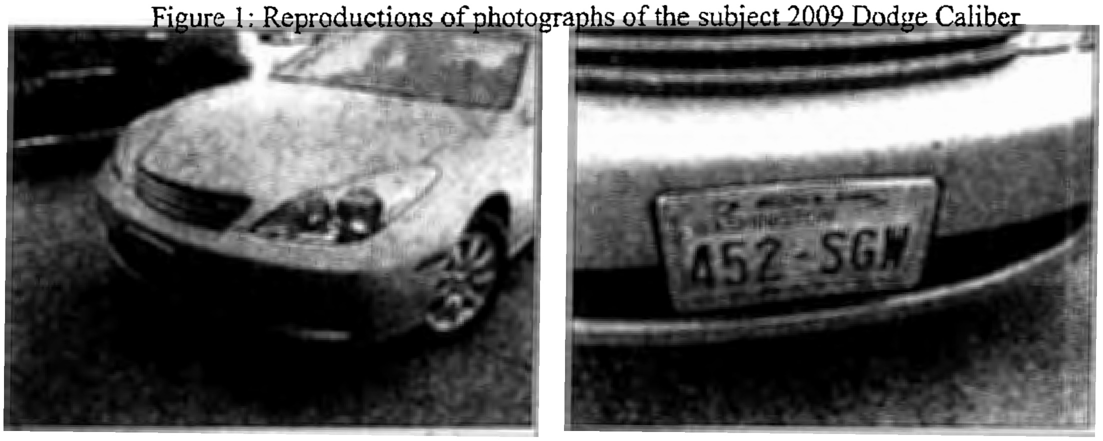

Figure 2: Reproductions of photographs of the incident 2004 Lexus ES330

Scientific analyses of the photographs, itemized repair records, geometric measurements of the vehicles, and testimony identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[11] The laws of physics dictate that the longitudinal force exerted to the subject Dodge Caliber was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the subject Dodge as a result of the sideswipe event was less than 1.8g.[12] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[13] the Delta-V associated with 1.8g of peak acceleration is 4.0 mph. Therefore, the subject Dodge Caliber in which Ms. Johnson was seated during the sideswipe event was exposed to a Delta-V of less than 4.0 mph with peak acceleration less than 1.8g. The lateral forces associated with the subject incident were calculated to be insignificant.

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11 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts. (SAE 950352). Warrendale, PA. Society of Automotive Engineers.

12 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions. (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

13 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA. Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Ms. Johnson experiences 1g of loading while in a sedentary state. Therefore, Ms. Johnson experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Johnson in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, Ms. Johnson was capable of performing household chores along with working as a hair stylist. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[14] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[15]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Dodge Caliber in which Ms. Johnson was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Johnson's claimed injuries in the subject incident.

Kinematic Analysis:

According to the State of Washington Police Traffic Collision Report, Ms. Johnson was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Johnson's principle direction of motion would be forward and slightly rightward, relative to the subject vehicle.

The laws of physics dictate that when the incident Lexus ES330 contacted the right side of the subject Dodge Caliber, had there been enough energy transferred to initiate motion; the Dodge would have been decelerated and pushed slightly leftward causing Ms. Johnson's body to move forward and slightly rightward relative to the interior of the subject vehicle. The three-point restraint that Ms. Johnson was reported to be wearing would have locked when the vehicle accelerations exceeded 0.7g,[16] thereby supporting and limiting body excursion. Friction generated at the seat bottom of Ms. Johnson, as well as the passive muscle resistance of her arms would have acted in conjunction with her three-point restraint to limit body motion. Provided the low accelerations of the subject incident, and the supports described, the bodily response of Ms. Johnson would have been limited to within normal physiological limits.

14 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.
15 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.
16 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

Findings:

1. On July 10, 2009, Ms. Yutta Johnson was the restrained driver of a 2009 Dodge Caliber that was contacted in the right side at low speed by a 2004 Lexus ES330.
2. The change in velocity was less than 4.0 miles-per-hour with peak accelerations less than 1.8g.
3. The acceleration experienced by Ms. Johnson was within the limits of human tolerance, the personal tolerance levels of Ms. Johnson and comparable to that experienced during various daily activities.

Evaluation of Biomechanical failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Johnson was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported injuries and the subject incident.[17,18]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If an biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

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17 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

18 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Cervical Spine

According to the available documents, Ms. Johnson was diagnosed with a cervical sprain/strain.

As described previously, the vehicle interaction would have caused rearward and slight leftward acceleration of the subject Dodge. Had the forces generated been sufficient to overcome Ms. Johnson's muscle reaction forces, her body would have moved forward and slightly rightward relative to the Dodge's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Dodge. Ms. Johnson's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[19] A kinematic analysis of Ms. Johnson's response to the subject incident demonstrated that her overall head motion would have been relatively minimal.[20,21] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[22] As a result, Ms. Johnson's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[23]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[24] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[25] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine biomechanical failure potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical biomechanical failure are greater that that associated with the subject incident.[26,27] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[28] None of the participants

19 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

20 Araszewski, M., Roenitz, E., and Toor, A., (1999) Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts, (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

21 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004) Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts, (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

22 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

23 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

24 Nielsen, G.P., Gough, J.P., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

25 Siegmund, G., and Williamson, P., (1993) "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

26 Ivancic, P.C., Ito, S., Panjabi, M.M., et al., (2005) "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." *Traffic Injury Prevention*, 6:175-184.

27 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al., (2005) "Frontal Impact Causes Ligamentous Cervical Spine Injury." *Spine*, 30(16):1852-1858.

28 Chandler, R.F., and Christian, R.A., (1970) Crash Testing of Humans in Automobile Seats, (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

reported any chronic cervical injuries. Arbogast et al.[29] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or biomechanical failure to any participants. Research by Weiss et al.[30] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[31,32] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Johnson cannot be made.

Thoracic and Lumbar Spine

According to the available documents, Ms. Johnson was diagnosed with a thoracic and lumbar sprain/strain.

In this type of collision, the motion of Ms. Johnson's thoracic and lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Ms. Johnson's muscle reaction forces, her body would have moved forward and slightly rightward relative to the Dodge's interior. As described previously, the State of Washington Police Traffic Collision Report reported Ms. Johnson was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[33] Therefore, Ms. Johnson's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Ms. Johnson's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[34] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was

[29] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009) Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests, (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[30] Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[31] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

[32] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

[33] Code of Federal Regulations, Federal Motor Vehicle Safety Standard, Title 49, Part 571, Section 209.

[34] Nielsen, G.P., Gough, J.P., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar injuries were reported. Siegmund and Williamson[35] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar injuries. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[36] None of the participants reported any chronic thoracic or lumbar spine injuries. Arbogast et al.[37] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or biomechanical failure to any participants. Research by Weiss et al.[38] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic biomechanical failure. The subject incident had a peak acceleration below 1.8g. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[39] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[40] Ms. Johnson's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Johnson, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

<u>Personal Tolerance Values</u>

As noted previously, according to the available documents, prior to the subject incident Ms. Johnson was capable of performing household chores. She was also noted to perform activities that required bending, kneeling, lifting, and walking while working as a hair stylist and while babysitting. These activities can produce greater movement, or stretch, to the soft tissues of Ms.

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35 Siegmund, G., and Williamson, P., (1993) "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

36 Chandler, R.F., and Christian, R.A., (1970) Crash Testing of Humans in Automobile Seats, (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

37 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009) Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests, (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

38 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

40 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

Johnson and produce comparable, if not greater, forces applied to the cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 10, 2009, Ms. Yutta Johnson was the restrained driver of a 2009 Dodge Caliber that was contacted in the right side at low speed by a 2004 Lexus ES330.
2. The severity of the subject incident was consistent with a Delta-V less than 4.0 miles-per-hour with peak acceleration less than 1.8g for the subject 2009 Dodge Caliber in which Ms. Johnson was seated.
3. The acceleration experienced by Ms. Johnson was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupant's body forward and slightly rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed thoracic and lumbar injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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By
FEB 19 2013
Law Offices of
Kelley J. Sweeney

February 8, 2013

Mario Cava, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Johnson, Yutta v. Max Harrison*
ARCCA Case No.: 3271-200

Dear Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Yutta Johnson. This letter is meant to supplement my report of October 16, 2012, regarding Yutta Johnson. Since that time, I have had the opportunity to review and evaluate additional documents related to the subject incident on July 10, 2009. Furthermore, the additional documents do not change my opinion of my previous analysis.

Additional Information Reviewed:

In the course of my analysis regarding Yutta Johnson, I reviewed the additional materials:

- Additional Medical Records pertaining to Yutta Johnson

Evaluation of Injury Mechanisms:

Left Shoulder

According to the additional medical documents, Ms. Johnson was diagnosed with left shoulder impingement and rotator cuff bursitis.

There is no reason to assume that the claimed left shoulder injuries are causally related to the subject incident. Injuries to the shoulder occur when an event consists of both the appropriate injury mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. A rotator cuff sprain, or shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder injuries are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[1] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly injured during repetitive use of

[1] Moore, K.L. and Dalley, A.F., (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[2,3] According to the available documents, Ms. Johnson worked as a hair dresser, a job that consists of repetitive motions for long periods of time. Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[4,5,6,7]

As stated in my original report, the subject incident vehicle interaction would have caused rearward and slight leftward acceleration of the subject Dodge. The State of Washington Police Traffic Collision Report and other available documents indicate that Ms. Johnson was pushed into the left armrest. This is contrary to the motions of the subject incident, had the forces generated been sufficient to overcome Ms. Johnson's muscle reaction forces, her body would have moved forward and slightly rightward (away from the driver's door/armrest) relative to the Dodge's interior. This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Dodge. The three-point restraint forces would have been minimal and distributed over strong bony elements such as his pelvis, torso, and clavicle. The low accelerations in the subject incident and the restraint provided by the three-point restraint and seat bottom, then, were such that any motion of Ms. Johnson's left shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder injuries of Ms. Johnson cannot be made.

Conclusions:

Based upon the additional information my opinions from my report dated October 16, 2012, have not changed.

Additionally, based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. There is no injury mechanism present in the subject incident to account for Ms. Johnson's claimed left shoulder injuries. As such, a causal relationship between the subject incident and the left shoulder injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

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[2] Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

[3] Braun, S., Kokmeyer, D., and Millett, P.J., et al., (2009). "Shoulder Injuries in the Throwing Athlete." Journal of Bone and Joint Surgery 91: 966-978.

[4] Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

[5] Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

[6] Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

[7] Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

ARCCA

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

ARCCA, INCORPORATED
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PHONE 877-942-7222 **FAX** 206-547-0759
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October 19, 2012

Melinda Wieder, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Lynds, Casey v. Elipidio Mangaoang and Evelyn Mangaoang*
Claim No.: 33241054036
ARCCA Case No.: 3271-208

Dear Ms. Wieder:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed diagnosed conditions involved in the incident of Casey Lynds. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents and testimony, on November 30, 2010, Mr. Casey Lynds was the restrained driver of a 2006 Toyota Tacoma traveling northbound on Washington Street near 4th Avenue South in Seattle, Washington. Mr. Elipidio Mangaoang was the driver of a 2009 Honda CRV traveling on Washington Street directly behind the Toyota. According to the available documents, the Toyota was stopped for a red traffic signal and the Honda failed to stop in time. As a result, the front of the incident Honda contacted the rear of the subject Toyota. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 2006 Toyota Tacoma
- Seventeen (17) color photographic reproductions of the incident 2009 Honda CRV
- First National Insurance Company of America repair estimate for the subject 2006 Toyota Tacoma [December 8, 2010]
- Careys Autobody Inc. repair estimate for the subject 2006 Toyota Tacoma [December 13, 2010]
- First National Insurance Company of America repair estimate for the in subject 2006 Toyota Tacoma [December 8, 2010]
- First National Insurance Company of America repair estimate for the incident 2009 Honda CRV [December 10, 2010]
- Defendants' First Set of Interrogatories and Requests for Production of Documents to Plaintiff and Responses Thereto, *Casey J. Lynds v. Elipidio Mangaoang and Evelyn Mangaoang* [July 25, 2012]
- Deposition Transcript of Casey J. Lynds [October 11, 2012]
- Medical Records pertaining to Casey Lynds
- VinLink data sheet for the subject 2006 Toyota Tacoma
- Expert AutoStats data sheets for a 2006 Toyota Tacoma
- VinLink data sheet for the incident 2009 Honda CRV
- Expert AutoStats data sheets for a 2009 Honda CRV

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the diagnosed conditions that Mr. Lynds claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Lynds was occupying;
3. Determine Mr. Lynds's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported diagnosed conditions and determine whether the defined biomechanical failure mechanisms were created during Mr. Lynds's response to the subject incident;
5. Evaluate Mr. Lynds's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported diagnosed conditions.

If the subject incident created the biomechanical failure mechanisms that generate the reported diagnosed conditions, a causal link between the diagnosed conditions and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported diagnosed conditions, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Lynds has reported the following diagnosed conditions as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota Tacoma and incident Honda CRV in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Toyota and the Honda, where the primary points of impact to the incident Honda and the subject Toyota were to the front and rear, respectively.

The damage estimate of the subject Toyota Tacoma indicated damage primarily to the rear face bar, right step pad extension, rear cover, right side inner plate, and right corner reinforcement; which is consistent with the reviewed photographic reproductions (Figure 1). Mr. Lynds testified the damage to the subject Toyota was to the tow hitch along with the rear bumper hanging down and creased. The damage estimate of the incident Honda CRV indicated damage primarily to the front license frame; which is consistent with the reviewed photographic reproductions (Figure 2). Additionally, Mr. Lynds testified the damage to the incident Honda was to the front bumper.

Figure 1: Reproductions of photographs of the subject 2006 Toyota Tacoma

Figure 2: Reproductions of photographs of the incident 2009 Honda CRV

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an engineering analysis of the forces sustained by the incident Honda can be used to resolve the loads sustained by the subject Toyota. That is, the forces sustained by the incident Honda are equal and opposite to those of the subject Toyota.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the incident Honda CRV and geometric measurements of a 2009 Honda CRV revealed the damage due to the subject incident. An engineering analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Honda CRV would result in significant and visibly noticeable crush across the front of the incident vehicle's front structure, with a residual

11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

crush of 3.25 inches. Therefore, the engineering analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the front of the incident Honda CRV indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the above analysis is consistent with an energy crush analysis for the subject 2006 Toyota Tacoma.

Review of the vehicle damage, incident data, published literature, engineering analyses, conservation of momentum and my experience indicates an incident resulting in a Delta-V of less than 9.2 miles-per-hour for the subject Toyota Tacoma. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 9.2 mile-per-hour impact is 2.8g.[18] By the laws of physics, the average acceleration experienced by the subject Toyota Tacoma in which Mr. Lynds was seated was less than 2.8g.

The acceleration experienced due to gravity is 1g. This means that Mr. Lynds experiences 1g of loading while in a sedentary state. Therefore, Mr. Lynds experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Lynds in his daily life would have increased the loading to his body beyond the sedentary 1g. Mr. Lynds testified that prior to the subject incident he would play sports and ride his motorcycle up to four times a week. Additionally, he testified that he worked as a surgical assistant, which required him to set up for surgeries and lift boxes weighing 40-50 lbs. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota in which Mr. Lynds was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Mr. Lynds's claimed diagnosed conditions in the subject incident.

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17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

Kinematic Analysis:

According to his testimony, Mr. Lynds was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Lynds's principle direction of motion would be rearward, relative to the subject vehicle. Additionally, the available documents indicate Mr. Lynds was not braced and unaware of the impending impact.

The laws of physics dictate that when the incident Honda contacted the rear of the subject Toyota, had there been enough energy transferred to initiate motion, the Toyota would have been pushed forward causing Mr. Lynds's seat to move forward relative to his body, which would result in Mr. Lynds moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Lynds and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Mr. Lynds would have been limited to well within the range of normal physiological limits.

Findings:

1. On November 30, 2010, Mr. Casey Lynds was the restrained driver of a 2006 Toyota Tacoma that was contacted in the rear at low speed by a 2009 Honda CRV.
2. The change in velocity was less than 9.2 miles-per-hour with average accelerations less than 2.8g.
3. The acceleration experienced by Mr. Lynds was within the limits of human tolerance, the personal tolerance levels of Mr. Lynds and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Lynds was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported diagnosed conditions and the subject incident.[24,25]

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed diagnosed conditions cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the diagnosed conditions cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Mr. Lynds was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed diagnosed cervical conditions are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota Tacoma would be pushed forward and Mr. Lynds would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 Toyota Tacoma showed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.5 inches in the full down position and 33.75 inches in the full up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Lynds's age (23 years), height (71 inches) and weight (162 lbs), Mr. Lynds has a normal seated height of 34.9 inches. Thus the seat is tall enough to have prevented hyperextension of Mr. Lynds and one would not expect to see any conditions greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failure to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failure.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Lynds in the subject incident. The subject incident had an average acceleration less than 2.8g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Mr. Lynds would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

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26 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

27 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

29 Ito, S., Ivancic, P.C., et al., (2004) “Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) “The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation,* 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) “Thoracic and Lumbar Spine Accelerations in Everyday Activities”, Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) “The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities”, Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported diagnosed cervical spine conditions of Mr. Lynds cannot be made.

Thoracic Spine

According to the available documents, Mr. Lynds was diagnosed with a thoracic sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 2.8g. Mr. Lynds's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine

[34] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[35] Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[36] Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[37] Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Lynds, a causal link between the subject incident and claimed diagnosed thoracic conditions cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On November 30, 2010, Mr. Casey Lynds was the restrained driver of a 2006 Toyota Tacoma that was contacted in the rear at low speed by a 2009 Honda CRV.
2. The severity of the subject incident was consistent with a Delta-V less than 9.2 miles-per-hour with an average acceleration less than 2.8g for the subject 2006 Toyota Tacoma in which Mr. Lynds was seated.
3. The acceleration experienced by Mr. Lynds was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Lynds's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Lynds's claimed diagnosed cervical conditions. As such, a causal relationship between the subject incident and the diagnosed cervical conditions cannot be made.

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[38] Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[39] Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3):184-191.

[40] Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

[41] Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[42] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

[43] Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Lynds's claimed diagnosed thoracic spine conditions. As such, a causal relationship between the subject incident and the diagnosed thoracic conditions cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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November 1, 2012

Alice Morales-Galvez, Esquire
Alice Morales-Galvez, Attorney at Law
901 5th Avenue, Suite 830
Seattle, WA 98164

Re: *Jones, Clifton v. Thien Huong Ong*
File No.: 0119479335.1 SPR
ARCCA Case No.: 4054-015

Dear Ms. Morales-Galvez:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Clifton Jones. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

According to the available documents, on September 18, 2008, Mr. Clifton Jones was the restrained driver of a 2004 Cadillac Seville traveling in the Lynnwood Park and Ride parking lot in Lynnwood, Washington. Ms. Thien Huong Ong was the driver of a 2003 Mitsubishi Outlander traveling in the Lynnwood Park and Ride behind the Cadillac. According to the available documents, the Cadillac driver was attempting to straighten his vehicle in a parking space and was struck from behind by the incident Mitsubishi. As a result, the rear bumper of the incident Mitsubishi contacted the rear of the subject Cadillac. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eight (8) grayscale photographic reproductions of the subject 2004 Cadillac Seville
- Two (2) color photographic reproductions of the incident 2003 Mitsubishi Outlander
- Allstate Insurance Company repair estimate for the subject 2004 Cadillac Seville [September 23, 2008]
- Recorded Statement Transcript of Clifton Jones [September 19, 2008]
- Recorded Statement Transcript of Huong Ong [September 19, 2008]
- Deposition Transcript of Huong Thien Ong [June 21, 2012]
- Deposition Transcript of Clifton Jones [June 15, 2012]
- Medical Records pertaining to Clifton Jones
- VinLink data sheet for the subject 2004 Cadillac Seville
- Expert AutoStats data sheets for a 2004 Cadillac Seville
- Expert AutoStats data sheets for a 2000 Cadillac Seville
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2000 Cadillac Seville
- Expert AutoStats data sheets for a 2003 Mitsubishi Outlander

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Jones claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Jones was occupying;
3. Determine Mr. Jones's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Jones's response to the subject incident;
5. Evaluate Mr. Jones's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Jones has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Nondisplaced fracture at C6
  - Exacerbation of cervical disc conditions
- Lumbar Spine
  - Sprain/strain
  - Exacerbation of lumbar disc conditions

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Cadillac Seville and incident Mitsubishi Outlander in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Cadillac and the Mitsubishi, where the primary points of impact to the incident Mitsubishi and the subject Cadillac was to the rear of both vehicles.

The damage estimate of the subject Cadillac Seville indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). Mr. Jones testified the damage to the subject Cadillac consisted of a hole pushed in the bumper and paint chipping. Ms. Ong testified that she did not see any damage to the subject Cadillac and there were two small scratches on the incident Mitsubishi due to the subject incident.

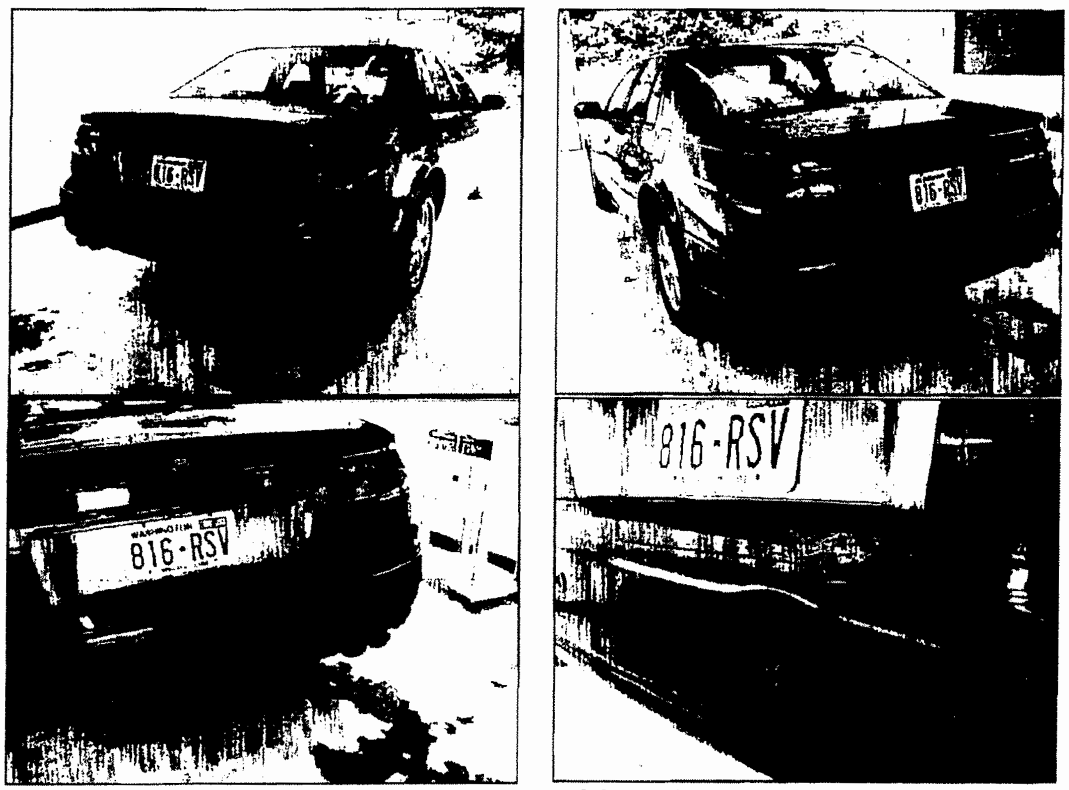

Figure 1: Reproductions of photographs of the subject 2004 Cadillac Seville

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Cadillac Seville, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2000 Cadillac Seville, essentially the same vehicle as a 2004 Cadillac Seville, in a five mile-per-

[11] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

hour rear impact into a flat barrier. The test Cadillac Seville sustained damage to the rear energy absorber and deformation of the rear body panel. The primary damage to the subject Cadillac was to the rear bumper cover. Thus, because the test Cadillac in the IIHS rear impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy crush analysis for a 2004 Cadillac Seville.[12,13,14,15,16]

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Cadillac Seville. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[17] By the laws of physics, the average acceleration experienced by the subject Cadillac in which Mr. Jones was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Mr. Jones experiences 1g of loading while in a sedentary state. Therefore, Mr. Jones experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Jones in his daily life would have increased the loading to his body beyond the sedentary 1g. Mr. Jones testified that he worked out 5 days a week at the gym including weight machines and walking on the treadmill. Additionally, he testified that at home he would garden, clean the roof, and perform general house cleaning. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[18] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[19]

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[12] Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

[13] Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

[14] Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

[15] Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

[16] Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

[17] Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA, Society of Automotive Engineers.

[18] Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

[19] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Cadillac in which Mr. Jones was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Jones's claimed injuries in the subject incident.

Kinematic Analysis:

According to his testimony, Mr. Jones was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Jones's principle direction of motion would be rearward, relative to his vehicle. Additionally, Mr. Jones testified that he was aware and braced for the impending impact.

The laws of physics dictate that when the incident Mitsubishi contacted the rear of the subject Cadillac, had there been enough energy transferred to initiate motion, the Cadillac would have been pushed forward causing Mr. Jones's seat to move forward relative to his body, which would result in Mr. Jones moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Jones and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[20,21,22] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Jones would have been limited to well within the range of normal physiological limits.

Findings:

1. On September 18, 2008, Mr. Clifton Jones was the restrained driver of a 2004 Cadillac Seville that was contacted in the rear at low speed by a 2003 Mitsubishi Outlander.
2. The change in velocity was at or below the test speed of 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Mr. Jones was within the limits of human tolerance, the personal tolerance levels of Mr. Jones and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Jones was well

[20] Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[21] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[22] Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[23,24]

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or injury to intervertebral discs occurs when an environment creates both a mechanism for injury and a force magnitude sufficient to exceed the strength capacity of the disc. Disc injury can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (injury) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[25]

Cervical Spine

According to a cervical MRI dated October 20, 2008, there were findings consistent with degeneration throughout the cervical spine and a suspected recent inferior endplate obliquely oriented fracture of the C6 vertebrae with little in the way of a compression deformity. A follow up cervical CT scan dated June 5, 2009, indicated there was no acute bony or articular injury and was in agreement with a prior cervical CT scan dated October 23, 2008. Additionally, the available documents indicate Mr. Jones was diagnosed with a cervical sprain/strain.

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23 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

24 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

25 White III, A.A. and M.M. Panjabi, (1990) Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Cadillac would be pushed forward and Mr. Jones would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 1999 Cadillac Seville, essentially the same vehicle as a 2000 Cadillac Seville, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 29.0 inches in the full-down position and 31.5 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Jones's age (65 years), height (74 inches) and weight (210 lbs), Mr. Jones would have a normal seated height of 36.4 inches. Mr. Jones testified that the headrest was adjusted to his level of comfort. Thus it would be expected that the seat is tall enough to have prevented hyperextension of Mr. Jones and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[28] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

[29] Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

to that experienced by Mr. Jones in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Mr. Jones would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries and/or exacerbation of preexisting cervical spine injuries of Mr. Jones cannot be made.

Lumbar Spine

According to a lumbar MRI dated October 20, 2008, there were findings consistent with multiple levels that appear to have broad based annular tears of bulging discs versus shallow disc protrusions and disc degeneration at L5-S1. Additionally, Mr. Jones was diagnosed with a lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 1.5g. Mr. Jones's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/injuries. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Jones, a causal link between the

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34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts. (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

36 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

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subject incident and claimed lumbar injuries and /or exacerbation of preexisting lumbar injuries cannot be made.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On September 18, 2008, Mr. Clifton Jones was the restrained driver of a 2004 Cadillac Seville that was contacted in the rear at low speed by a 2003 Mitsubishi Outlander.
2. The severity of the subject incident was consistent with a Delta-V equal to or less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 2004 Cadillac Seville in which Mr. Jones was seated.
3. The acceleration experienced by Mr. Jones was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Jones's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no injury mechanism present in the subject incident to account for Mr. Jones's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.
6. There is no injury mechanism present in the subject incident to account for Mr. Jones's claimed lumbar spine injuries. As such, a causal relationship between the subject incident and the lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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EXHIBIT
Probst 28
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November 16, 2012

Kim McClay, Esquire
Drazkowski & Moore
19909 120th Avenue NE Suite 201
Bothell, WA 98011

Re: *Jiminez-Garcia, Alejandro v. Kaitlyn Richardson*
ARCCA Case No.: 1860-040

Dear Ms. McClay:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed injuries involved in the incident of Alejandro Jiminez-Garcia. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On April 28, 2011, Mr. Alejandro Jiminez-Garcia was the restrained driver of a 2003 Ford Escape traveling northbound on I-405 in Renton, Washington. Ms. Kaitlyn Richardson was the driver of a 2007 Toyota 4Runner traveling northbound on I-405 directly behind the Ford. According to the available documents, the Ford was slowing down for traffic and was struck from behind by the incident Toyota. As a result, the front bumper of the incident Toyota contacted the rear of the subject Ford. The subject vehicle was capable of driving from the incident scene and the airbags were not deployed as a result of the impact.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Ten (10) color photographic reproductions of the subject 2003 Ford Escape
- Twenty-two (22) color photographic reproductions of the incident 2007 Toyota 4Runner
- Progressive Universal Insurance – Estimate for the subject 2003 Ford Escape
- Deposition Transcript of Alejandro Jiminez-Garcia [October 18, 2012]
- Medical Records pertaining to Alejandro Jiminez-Garcia
- VinLink data sheet for the subject 2003 Ford Escape
- Expert AutoStats data sheets for a 2003 Ford Escape
- Expert AutoStats data sheets for a 2001 Ford Escape
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2001 Ford Escape
- VinLink data sheet for the incident 2007 Toyota 4Runner
- Expert AutoStats data sheets for a 2007 Toyota 4Runner
- Expert AutoStats data sheets for a 2003 Toyota 4Runner
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2003 Toyota 4Runner

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the engineering community and is an established approach to assessing injury causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the injuries that Mr. Jiminez-Garcia claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Jiminez-Garcia was occupying;
3. Determine Mr. Jiminez-Garcia's kinematic response within the vehicle as a result of the subject incident;
4. Define the injury mechanisms known to cause the reported injuries and determine whether the defined injury mechanisms were created during Mr. Jiminez-Garcia's response to the subject incident.
5. Evaluate Mr. Jiminez-Garcia's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of engineering certainty whether a causal relationship exists between the subject incident and his reported injuries.

If the subject incident created the injury mechanisms that generate the reported injuries, a causal link between the injuries and the event cannot be ruled out. If, the subject incident did not create the injury mechanisms associated with the reported injuries, then a causal link to the subject incident cannot be established.

Injury Summary:

According to the available documents, Mr. Jiminez-Garcia has reported the following injuries as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Ford Escape and incident Toyota 4Runner in association with accepted engineering methodologies. According to the available documents, the subject incident was a rear impact between the Ford and the Toyota, where the primary points of impact to the incident Toyota and the subject Ford were to the front and rear, respectively.

The damage estimate of the subject Ford Escape indicated damage primarily to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). The reviewed photographic reproductions of the incident Toyota 4Runner depict minor to no damage (Figure 2).

Figure 1: Reproductions of the subject 2003 Ford Escape

ARCCA

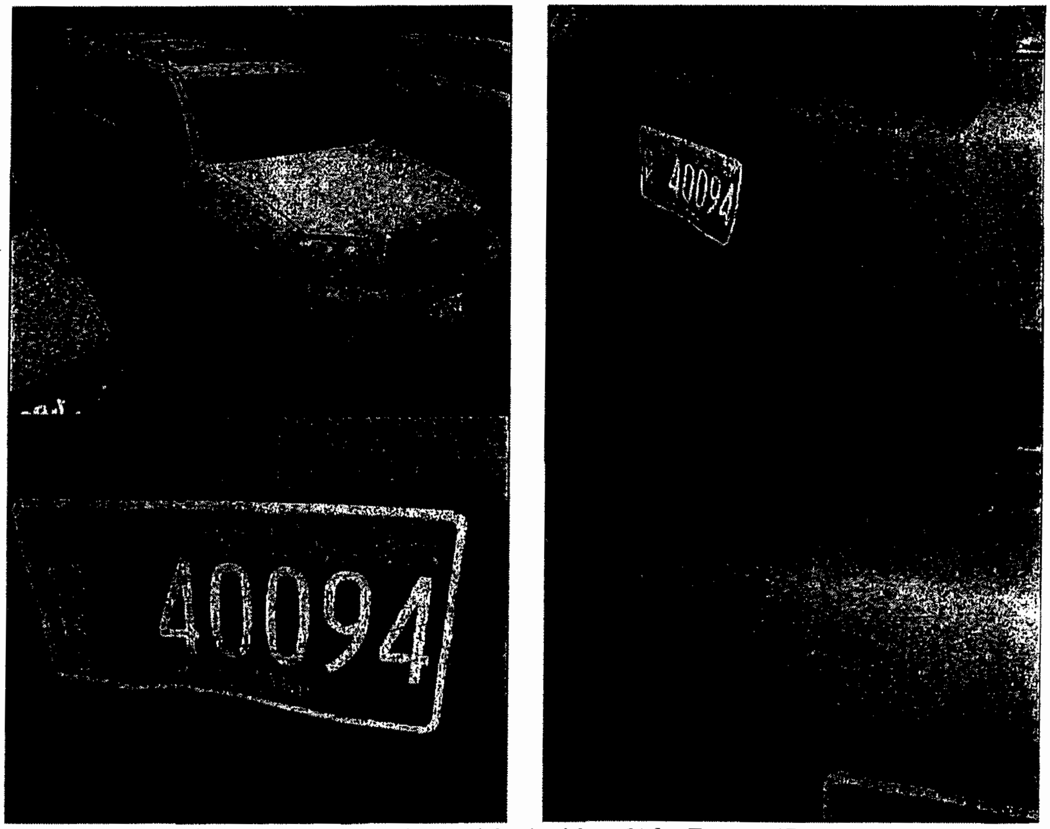

Figure 2: Reproductions of the incident 2007 Toyota 4Runner

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Ford Escape, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2001 Ford Escape, essentially the same vehicle as a 2003 Ford Escape, in a five mile-per-hour rear impact into a flat barrier. The test Ford sustained damage to the rear bumper cover and trailer hitch. The primary damage to the subject Ford was to the rear bumper cover. Thus, because the test Ford in the IIHS rear impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 2003 Ford Escape and an IIHS low-speed crash test for a 2003 Toyota 4 Runner.[12,13,14,15,16,17]

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[11] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[12] Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

[13] Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of less than 5 miles-per-hour for the subject Ford Escape. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[18] By the laws of physics, the average acceleration experienced by the subject Ford in which Mr. Jiminez-Garcia was seated was less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Mr. Jiminez-Garcia experiences 1g of loading while in a sedentary state. Therefore, Mr. Jiminez-Garcia experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Jiminez-Garcia in his daily life would have increased the loading to his body beyond the sedentary 1g. According to his testimony, prior to the subject incident Mr. Jiminez-Garcia participated in swimming. Additionally Mr. Jiminez-Garcia was employed as a finish carpenter. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Ford in which Mr. Jiminez-Garcia was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism for Mr. Jiminez-Garcia's claimed injuries in the subject incident.

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14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

Kinematic Analysis:

According to his testimony, Mr. Jiminez-Garcia was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. Jiminez-Garcia's principle direction of motion would be rearward, relative to his vehicle. Additionally, Mr. Jiminez-Garcia testified that he was unaware of the impending impact.

The laws of physics dictate that when the incident Toyota contacted the rear of the subject Ford, had there been enough energy transferred to initiate motion, the Ford would have been pushed forward causing Mr. Jiminez-Garcia's seat to move forward relative to his body, which would result in Mr. Jiminez-Garcia moving rearward relative to the interior of the subject vehicle. This interaction between Mr. Jiminez-Garcia and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. Jiminez-Garcia would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 28, 2011, Mr. Alejandro Jiminez-Garcia was the belted driver of a 2003 Ford Escape that was contacted in the rear at low speed by a 2007 Toyota 4Runner.
2. The change in velocity was less than 5 miles-per-hour with average accelerations less than 1.5g.
3. The acceleration experienced by Mr. Jiminez-Garcia was within the limits of human tolerance, the personal tolerance levels of Mr. Jiminez-Garcia and comparable to that experienced during various daily activities.

Evaluation of Injury Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Jiminez-Garcia was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no injury mechanism present to causally link his reported injuries and the subject incident.[24,25]

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed injury is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known injury mechanism?
2. If an injury mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the injury mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed injuries cannot be ruled out. If, however, the injury mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the injuries cannot be made.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Mr. Jiminez-Garcia was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical injuries are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford would be pushed forward and Mr. Jiminez-Garcia would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for injury of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" injury to the neck. The primary mechanism for this type of injury occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2002 Ford Escape, essentially the same vehicle as a 2003 Ford Escape, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30 inches in the "full down" position and 33.5 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Jiminez-Garcia's age (40 years), height (71 inches) and weight (165 lbs), Mr. Jiminez-Garcia would have a normal seated height of 35.1 inches. Thus the seat is tall enough to have prevented hyperextension of Mr. Jiminez-Garcia and one would not expect to see any injuries greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic injuries to the cervical spine.

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[25] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical injury. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical injuries.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain injury threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. Jiminez-Garcia in the subject incident. The subject incident had an average acceleration less than 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Mr. Jiminez-Garcia would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required injury mechanism and did not create

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26 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

27 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Mr. Jiminez-Garcia cannot be made.

Thoracic and Lumbar Spine

According to the available documents, Mr. Jiminez-Garcia was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic injury mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or injury, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no injury to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and injury has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration less than 1.5g. Mr. Jiminez-Garcia's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine

34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

36 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required injury mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Jiminez-Garcia, a causal link between the subject incident and claimed thoracic and lumbar injuries cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, prior to the subject incident Mr. Jiminez-Garcia was employed as a finish carpenter. He also participated in swimming. He would be required to perform activities that required bending, kneeling, lifting, and walking while working. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Jiminez-Garcia and produce comparable, if not greater, forces applied to the cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On April 28, 2011, Mr. Alejandro Jiminez-Garcia was the belted driver of a 2003 Ford Escape that was contacted in the rear at low speed by a 2007 Toyota 4Runner.
2. The severity of the subject incident was consistent with a Delta-V less than 5 miles-per-hour with an average acceleration less than 1.5g for the subject 2003 Ford Escape in which Mr. Jiminez-Garcia was seated.
3. The acceleration experienced by Mr. Jiminez-Garcia was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Jiminez-Garcia's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

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41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

5. There is no injury mechanism present in the subject incident to account for Mr. Jiminez-Garcia's claimed cervical injuries. As such, a causal relationship between the subject incident and the cervical injuries cannot be made.

6. There is no injury mechanism present in the subject incident to account for Mr. Jiminez-Garcia's claimed thoracic and lumbar spine injuries. As such, a causal relationship between the subject incident and the thoracic and lumbar injuries cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomedical Engineer

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November 29, 2012

Mario Cava, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Wu, Zhiping and Hai-Xing Zeng v. Laksmi V. Gottumukkala*
Claim No.: 207359074033
ARCCA Case No.: 3271-213

Dear Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Zhiping Wu and Hai-Xing Zeng. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.
2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.
3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.
4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.
5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on July 25, 2011, Mr. Zhiping Wu was the driver of a 2007 GMC Sierra traveling northbound on Alaskan Way in Seattle, Washington. Mr. Hai-Xing Zeng was the right front passenger of the 2007 GMC Sierra. Ms. Laksmi Gottumukkala was the driver of a 2004 Lexus RX330 traveling on Alaskan Way directly behind the GMC. According to the available documents, the GMC was stopped for traffic and was struck from behind by the incident Lexus. As a result, the front of the incident Lexus contacted the rear of the subject GMC. No airbags were deployed as a result of the impact, and both vehicles were capable of driving from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Case No. 11-241211
- Thirteen (13) color photographic reproductions of the subject 2007 GMC Sierra
- Eleven (11) color photographic reproductions of the incident 2004 Lexus RX 330
- Fix Auto Seattle Metro - Estimate of Record for the subject 2007 GMC Sierra [March 21, 2012]
- Bellevue Auto Rebuild, Inc. – Estimate of Record for the incident 2004 Lexus RX 330 [July 25, 2011]
- Bellevue Auto Rebuild – Supplement of Record for the incident 2004 Lexus RX 330 [August 10, 2011]
- Personal Injury Claim of *Zhiping Wu, and Hai-Xing Zeng* [April 30, 2012]
- Medical Records pertaining to Zhiping Wu
- Medical Records pertaining to Hai-Xing Zeng
- VinLink data sheet for the subject 2007 GMC Sierra
- Expert AutoStats data sheets for a 2007 GMC Sierra
- VinLink data sheet for the incident 2004 Lexus RX 330
- Expert AutoStats data sheets for a 2004 Lexus RX 330

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that the occupants claim were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle the occupants were occupying;
3. Determine the occupants' kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the occupants' responses to the subject incident.
5. Evaluate the occupants' personal tolerances in the context of their pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Mr. Zhiping Wu has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar and Sacral Spine
  - Sprain/strain
- Elbows and Hands
  - Sprain/strain
- Shoulders
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

According to the available documents, Mr. Hai-Xing Zeng has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Chest, Thoracic, Lumbar and Sacral Spine
  - Sprain/strain
- Hands
  - Sprain/strain
- Shoulders
  - Sprain/strain

<u>Damage and Incident Severity:</u>

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject GMC Sierra and incident Lexus RX330 in association with accepted methodologies. According to the available documents, the subject incident was a rear impact between the GMC and the Lexus, where the primary points of impact to the incident Lexus and the subject GMC were to the front and rear, respectively.

The damage estimate of the subject GMC Sierra indicated damage primarily to the left hinge bed side and left hinge gate side; which is consistent with the reviewed photographic reproductions (Figure 1). The supplemental damage estimate of the incident Lexus RX330 indicated damage primarily to the front bumper cover, right side support, right and left front bumper cover bracket, right headlamp assembly, left upper inner headlamp bracket, radiator upper tie bar, radiator right and left side support, radiator lock support, radiator right deflector, radiator, shroud, A/C condenser, hood, lock, safety catch, grille, right hinge, right fender assembly and low/high note horn; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproductions of photographs of the subject 2007 GMC Sierra

Figure 2: Reproductions of photographs of the incident 2004 Lexus RX330

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that an analysis of the forces sustained by the incident Lexus can be used to resolve the loads sustained by the subject GMC. That is, the forces sustained by the incident Lexus are equal and opposite to those of the subject GMC.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the repair estimate of

11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

the incident Lexus RX330 and geometric measurements of a 2004 Lexus RX330 revealed the damage due to the subject incident. A scientific analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Lexus RX330 would result in significant and visibly noticeable crush across the entirety of the incident vehicle's front structure, with a residual crush of 3.25 inches. This is calculated as permanent crush to the bumper and structure of the vehicle. Because of the bumper mismatch, the bumpers did not make direct contact and the incurred crush was directly into the non-bumper areas of the Lexus. An accepted methodology calls for reducing the deformation by 50% when override occurs when performing crush calculations or averaging the overall crush and bumper crush.[17] This is due to the under-ride event where softer non-structural components were contacted.[18,19,20] Therefore, the analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident. The lack of significant structural crush to the front of the incident Lexus RX330 indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Review of the vehicle damage, incident data, published literature, conservation of momentum, scientific analyses, conservation of momentum, and my experience indicates an incident resulting in a Delta-V significantly below 7.3 miles-per-hour for the subject GMC Sierra. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the average acceleration associated with a 7.3 mile-per-hour impact is 1.7g.[21] By the laws of physics, the average acceleration experienced by the subject GMC in which the occupants were seated was less than 1.7g.

The acceleration experienced due to gravity is 1g. This means that Mr. Wu and Mr. Zeng experience 1g of loading while in a sedentary state. Therefore, the occupants experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Mr. Wu and Mr. Zeng in their daily lives would have increased the loading to their body beyond the sedentary 1g.

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12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N. and Smith, R., *Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View*, Society of Automotive Engineers, Warrendale, PA, Publication 880072, 1988.

18 Szabo, T. J., Welcher, J. B., et al. (1992). Dynamics of Low Speed Crash Tests with Energy Absorbing Bumpers (SAE 921573). Warrendale, PA, Society of Automotive Engineers.

19 Nolan, JM, Brumbelow, M, Zuby, DS, et al. (2004). Important Considerations in the Development of a Test to Promote Stable Bumper Engagement in Low-Speed Crashes. (SAE 2004-01-1319). Warrendale, PA, Society of Automotive Engineers.

20 Fugger, TF, Randles, BC, Welcher, JB, Szabo, TJ. (2003). Vehicle and Occupant kinematics in Low-Speed Override/Underride Collisions. (SAE 2003-01-0158). Warrendale, PA, Society of Automotive Engineers.

21 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[22] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[23]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the GMC in which the occupants were seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for the occupants' claimed biomechanical failures in the subject incident.

Kinematic Analysis:

Presently, it is unknown whether Mr. Wu and Mr. Zeng were wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, the occupants' principle direction of motion would be rearward, relative to the subject vehicle.

The laws of physics dictate that when the incident Lexus contacted the rear of the subject GMC, had there been enough energy transferred to initiate motion, the GMC would have been pushed forward causing the occupants' seats to move forward relative to their bodies, which would result in the occupants moving rearward relative to the interior of the subject vehicle. This interaction between the occupants and the subject vehicle's interior would cause their bodies to load into the seatback structures. Specifically, their torsos and pelvis would settle back into the seatbacks. The low accelerations resulting from this collision would have caused little, or no, forward rebound of their bodies away from the seat backs.[24,25,26] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and the available seat belt system, then, were such that any motion of the occupants would have been limited to well within the range of normal physiological limits.

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[22] Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

[23] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

[24] Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[25] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[26] Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

Findings:

1. On July 25, 2011, Mr. Zhipping Wu was the driver of a 2007 GMC Sierra that was contacted in the rear at low speed by a 2004 Lexus RX330. Mr. Hai-Xing Zeng was the right front passenger of the 2007 GMC Sierra.
2. The change in velocity was significantly below 7.3 miles-per-hour with average accelerations less than 1.7g.
3. The acceleration experienced by the occupants was within the limits of human tolerance, the personal tolerance levels of the occupants and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the occupants was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link their reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

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27 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

28 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Cervical Spine

According to the available documents, Mr. Wu and Mr. Zeng were diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the GMC would be pushed forward and the occupants would have moved rearward relative to the vehicle, until their motion was stopped by the seatbacks. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 GMC Sierra 1500 showed that the nominal height of the front seats with an unoccupied, uncompressed seat is 30.0 inches in the full down position and 32.0 inches in the full up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. Wu's age (42 years), height (69 inches, 50th percentile male) and weight (172 lbs, 50th percentile male), Mr. Wu would have a normal seated height of 34.3 inches. Based on an anthropometric regression of Mr. Zeng's age (31 years), height (69 inches, 50th percentile male) and weight (172 lbs, 50th percentile male), Mr. Zeng would have a normal seated height of 34.3 inches. Thus the seat is tall enough to have prevented hyperextension for an average occupant and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failures to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[29] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[30] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical

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[29] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[30] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

failures.[31] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[32] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by the occupants in the subject incident. The subject incident had an average acceleration less than 1.7g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[33,34] The occupants would not have been exposed to any loading or motion outside of their personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[35,36] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/biomechanical failures. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of the occupants cannot be made.

Chest, Thoracic, Lumbar and Sacral Spine

According to the available documents, Mr. Wu and Mr. Zeng were diagnosed with a thoracic, lumbar and sacral sprain/strain. Additionally, Mr. Zeng was diagnosed with a chest sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. Additionally, the sacral spine would settle into the seatback and seat cushion providing support. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the chest, thoracic and lumbar spine. Neither the mechanism nor

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31 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

32 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

33 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

34 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

35 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

36 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[37] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[38] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[39] The subject incident had an average acceleration less than 1.7g. The occupants' thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of their personal tolerance levels.[40,41,42,43,44] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[45] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[46]

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37 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

38 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

39 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

40 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

41 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

42 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3):184-191.

43 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

44 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

45 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

46 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of the occupants, a causal link between the subject incident and claimed chest, thoracic, lumbar and sacral biomechanical failures cannot be made.

Hands and Elbows

According to the available documents, Mr. Wu and Mr. Zeng were diagnosed with a hand sprain/strain. Additionally, Mr. Wu was diagnosed with an elbow sprain/strain

There is no reason to assume that the claimed hand and elbow biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the GMC Sierra would be pushed forward and the occupants would have moved rearward relative to the vehicle, until their motion was stopped by the seatback. This provides no means for Mr. Wu and Mr. Zeng to load their hands and elbows. Furthermore, as previously stated Mr. Wu and Mr. Zeng's bodies would have moved rearward and the interaction with the seatback and their body would have minimized their motion. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Mr. Wu and Mr. Zeng's bodies away from the seatback.[47] Any rebound that may have occurred would have been limited by the available restraint system. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause biomechanical failure to their hands and elbows.

The subject incident had an average acceleration level that was less than 1.7g. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[48]

The subject incident lacks the appropriate biomechanical failure mechanism to produce biomechanical failure to the hands and elbows. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Mr. Wu and Mr. Zeng would tend to move rearward relative to their vehicle. They would not have contacted their hands and elbows on any rigid interior object. The available documents did not note any bruising, laceration, or abrasions associated with interaction of the vehicle interior in the subject incident. For these reasons, a causal link between the subject incident and the hand and elbow biomechanical failures claimed by the occupants cannot be made.

Shoulders

According to the available documents, Mr. Wu and Mr. Zeng were diagnosed with shoulder sprains/strains.

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[47] Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[48] Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

There is no reason to assume that the claimed shoulder biomechanical failure is causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject GMC would be pushed forward and Mr. Wu and Mr. Zeng would have moved rearward relative to the vehicle, until their motion was halted by the seatbacks. This interaction with the seatback would both limit the motion of both their shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of the occupants' bodies away from the seatbacks.[49] Any rebound that may have occurred would have been limited by the available restraint system. Again, the occupants' three-point restraint would have locked when the vehicle accelerations exceeded 0.7g,[50] Any load acting on the shoulder area due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause shoulder trauma or biomechanical failure to their shoulders. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of occupants' shoulders would have been limited to well within the range of normal physiological limits.

Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. A rotator cuff sprain, or shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[51] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.

The subject incident had an average acceleration level that was less 1.7g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported. [52,53,54,55,56] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder

49 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

50 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

51 Moore, K.L. and Dalley, A.F., (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins.

52 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

53 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

54 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

55 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

56 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

loads that are comparable to, or greater than that associated with the subject incident.[57,58,59,60] As a result, the occupants' shoulders would not have been exposed to any loading forces outside their personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce trauma to the shoulders. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. They would not have contacted their shoulders on any rigid interior object. For these reasons, a causal link between the subject incident and the shoulder biomechanical failures claimed by the occupants cannot be made.

Conclusions:

Based upon a reasonable degree of scientific and biomedical certainty, I conclude the following:

1. On July 25, 2011, Mr. Zhiping Wu was the driver of a 2007 GMC Sierra that was contacted in the rear at low speed by a 2004 Lexus RX330. Mr. Hai-Xing Zeng was the right front passenger of the 2007 GMC Sierra.
2. The severity of the subject incident was consistent with a Delta-V significantly below 7.3 miles-per-hour with an average acceleration less than 1.7g for the subject 2007 GMC Sierra in which the occupants were seated.
3. The acceleration experienced by the occupants was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the occupants' bodies back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed chest, thoracic, lumbar and sacral spine biomechanical failures. As such, a causal relationship between the subject incident and the chest, thoracic, lumbar and sacral biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed hand and elbow biomechanical failures. As such, a causal relationship between the subject incident and the hand and elbow biomechanical failures cannot be made.

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[57] Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." *Journal of Biomechanics*, In Press.

[58] Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." *Clinical Biomechanics*, 19:586-594.

[59] Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

[60] Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." *Journal of Biomechanics,* 40:2139-2149.

8. There is no biomechanical failure mechanism present in the subject incident to account for the occupants' claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call. This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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January 3, 2013

Mario Cava, Esquire
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Re: *Choi, Doo Sun v. Julie McNeil*
Claim No.: 493772244020
ARCCA Case No.: 3271-227

Mr. Cava:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Doo Sun Choi. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association, the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The police did not respond to the incident scene, thus the following incident description is based upon the available documents. On August 31, 2010, Ms. Doo Sun Choi was the restrained driver of a 2007 Honda Accord traveling southbound on I-405. Ms. Julie McNeil was the driver of a Acura MDX traveling directly behind the Honda. According to the available documents, the Honda slowed for traffic and was struck from behind by the incident Acura. As a result, the front of the incident Acura contacted the rear of the subject Honda. No airbags were deployed as a result of the impact, and both vehicles were capable of driving from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eleven (11) color photographic reproductions of the subject 2007 Honda Accord
- Six (6) color photographic reproductions of the incident Acura MDX
- Centers 3 Collision Center – Estimate of Record for the subject 2007 Honda Accord
- Defense Statement Summary of Julie Colin [September 6, 2010]
- Medical Records pertaining to Doo Sun Choi
- VinLink data sheet for the subject 2007 Honda Accord
- Expert AutoStats data sheets for a 2007 Honda Accord
- Insurance Institute for Highway Safety Low-Speed Test Report for a 2007 Honda Accord
- Expert AutoStats data sheets for a 2006 Acura MDX

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Choi claims were caused by the subject incident;

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Choi was occupying;
3. Determine Ms. Choi's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Choi's response to the subject incident;
5. Evaluate Ms. Choi's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical failure Summary:

According to the available documents, Ms. Choi has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
- Shoulders
  - Tendonitis/tendinosis

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda Accord and incident Acura MDX in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Acura, where the primary points of impact to the incident Acura and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda Accord indicated damage to the rear bumper cover; which is consistent with the reviewed photographic reproductions (Figure 1). According to the available documents, no damage has been observed on the Acura MDX; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproductions of photographs of the subject 2007 Honda Accord

Figure 2: Reproductions of photographs of the incident Acura MDX

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Accord, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2007 Honda Accord in a 6.2 mile-per-hour rear impact into a flat barrier. The test Honda sustained damage to the rear deck lid, rear body panel assembly, right and left tail lamp assembly, rear bumper, bumper cover, and bumper absorber. The primary damage to the subject Honda was to the rear bumper cover. Thus, because the test Honda in the IIHS rear impact test sustained more damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below the test speed of 6.2 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crush analysis of a 2007 Honda Accord.[12,13,14,15,16]

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V less than 6.2 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.2 mile-per-hour impact is 1.9g.[17] By the laws of physics, the average acceleration experienced by the subject Honda in which Ms. Choi was seated was less than 1.9g.

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11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Ms. Choi experiences 1g of loading while in a sedentary state. Therefore, Ms. Choi experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Choi in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[18] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[19]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda in which Ms. Choi was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Choi's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

The available documents indicate that Ms. Choi was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Choi's principle direction of motion would be rearward, relative to the subject vehicle.

The laws of physics dictate that when the incident Acura contacted the rear of the subject Honda, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing Ms. Choi's seat to move forward relative to her body, which would result in Ms. Choi moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Choi and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[20,21,22] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint

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18 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

19 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

20 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

21 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

22 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

provided by the seatback and seat belt system, then, were such that any motion of Ms. Choi would have been limited to well within the range of normal physiological limits.

Findings:

1. On August 31, 2010, Ms. Doo Sun Choi was the belted driver of a 2007 Honda Accord that was contacted in the rear at low speed by a Acura MDX.
2. The change in velocity was less than 6.2 miles-per-hour with average accelerations less than 1.9g.
3. The acceleration experienced by Ms. Choi was within the limits of human tolerance, the personal tolerance levels of Ms. Choi and comparable to that experienced during various daily activities.

Evaluation of Biomechanical failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Choi was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[23,24]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

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[23] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[24] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of the Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Cervical Spine

According to the available documents, Ms. Choi was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and Ms. Choi would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2007 Honda Accord showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.5 inches in the "full down" position and 33.5 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Choi's age (46 years), height (63 inches) and weight (135 lbs), Ms. Choi has a normal seated height of 32.1 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Choi and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failures to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[25] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[26] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[27] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is

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25 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

26 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

27 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal,* 6:366-375.

5g.[28] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Choi in the subject incident. The subject incident had an average acceleration less than 1.9g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[29,30] Ms. Choi would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[31,32] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures and/or exacerbation of pre-existing cervical spine biomechanical failures of Ms. Choi cannot be made.

Thoracic and Lumbar Spine

According to the available documents, Ms. Choi was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading

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28 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

29 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

30 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

31 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

32 Ng, T.,P. Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[33] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[34] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[35] The subject incident had an average acceleration less than 1.9g. Ms. Choi's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[36,37,38,39,40] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[41] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[42]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Choi, a causal link between the subject incident

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33 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

34 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

35 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

36 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

37 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

38 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine,* 7(3): 184-191.

39 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics,* 16:549-559.

40 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

41 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

42 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

and claimed thoracic and lumbar biomechanical failures and/or exacerbation of pre-existing thoracic and lumbar biomechanical failures cannot be made.

Shoulders

According to the available documents, Ms. Choi was diagnosed with aggravation of tendonitis/tendinosis of the shoulders.

There is no reason to assume that the claimed shoulder biomechanical failures are causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Honda would be pushed forward and Ms. Choi would have moved rearward relative to the vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of both her shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Choi's body away from the seatback.[43] Any rebound that may have occurred of Ms. Choi's body would have been limited by the available restraint system. Again, Ms. Choi's three-point restraint would have locked when the vehicle accelerations exceeded 0.7g,[44] Any load acting on the shoulder area due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause biomechanical failure of the shoulder and/or exacerbation of pre-existing biomechanical failure of the shoulder accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Choi's shoulders would have been limited to well within the range of normal physiological limits.

Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. A rotator cuff sprain, or shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[45] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15]

The subject incident had an average acceleration level that was less 1.9g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported.[46,47,48,49,50] Previous research has shown that shoulder loads during activities of daily living such

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[43] Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[44] Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

[45] Moore, K.L. and Dalley, A.F., (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins.

[46] Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[51,52,53,54] As a result, Ms. Choi's shoulders would not have been exposed to any loading forces outside her personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce biomechanical failure to the shoulder and/or aggravation of pre-existing biomechanical failure to the shoulders. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. She would not have contacted her shoulders on any rigid interior object. For these reasons, a causal link between the subject incident and the shoulder biomechanical failures claimed by Ms. Choi cannot be made.

Personal Tolerance Values

According to the available documents, prior to the subject incident Ms. Choi was noted to exercise and participate in physical activities. After the subject incident Ms. Choi participated in range of motion studies for diagnostic purposes. These activities were performed without biomechanical failure. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Choi and produce comparable, if not greater, forces applied to the shoulder, cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 31, 2010, Ms. Doo Sun Choi was the belted driver of a 2007 Honda Accord that was contacted in the rear at low speed by a Acura MDX.
2. The severity of the subject incident was consistent with a Delta-V less than 6.2 miles-per-hour with an average acceleration less than 1.9g for the subject 2007 Honda Accord in which Ms. Choi was seated.
3. The acceleration experienced by Ms. Choi was within the limits of human tolerance and comparable to that experienced during various daily activities.

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47 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

48 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

49 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

50 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

51 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." *Journal of Biomechanics*, In Press.

52 Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." *Clinical Biomechanics*, 19:586-594.

53 Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

54 Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." *Journal of Biomechanics*, 40:2139-2149.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Choi's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Choi's claimed cervical spine biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Choi's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Choi's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call. This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

EXHIBIT
Probst 29
5-23-17 VMK

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THE BLAIR FIRM

January 22, 2013

Vivienne Alpaugh, Esquire
Vivienne Alpaugh, Attorney at Law
901 5th Ave Suite 830
Seattle, WA 98164

Re: *Tucker, Laura v. James Kurek*
ARCCA Case No.: 4054-013

Dear Ms. Alpaugh:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Laura Tucker. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1. Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.
2. Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.
3. Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.
4. King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.
5. King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the State of Washington Vehicle Collision Report and other available documents and testimony, on April 4, 2009, Mr. William Walker was the restrained driver of a 1990 Subaru Loyale traveling northbound on State Route 3 at the intersection of State Route 305 in Poulsho, Washington. Ms Laura Tucker was the restrained right front passenger of the 1990 Subaru Loyale. Mr. James Kurek was the driver of a 2007 Toyota Avalon traveling directly behind the Subaru. According to the available documents, the Subaru was stopped for a traffic signal and was struck from behind by the incident Toyota. As a result, the front of the incident Toyota contacted the rear of the subject Subaru. Both vehicles were capable of driving from the subject incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Vehicle Collision Report
- Twenty-one (21) grayscale photographic reproductions of the subject 1990 Subaru Loyale
- Allstate Insurance Company – Estimate for the subject 1990 Subaru Loyale [April 9, 2009]
- Allstate Insurance Company – Supplement 1 for the subject 1990 Subaru Loyale [April 9, 2009]
- Recorded Statement Transcript of James D. Kurek [November 13, 2009]
- Deposition Transcript of Laura J. Tucker [September 13, 2012]
- Medical Records pertaining to Laura Tucker
- VinLink data sheet for the subject 1990 Subaru Loyale
- Expert AutoStats data sheets for a 1990 Subaru Loyale
- VinLink data sheet for the incident 2007 Toyota Avalon
- Expert AutoStats data sheets for a 2007 Toyota Avalon

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Tucker claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Tucker was occupying;
3. Determine Ms. Tucker's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Tucker's response to the subject incident;
5. Evaluate Ms. Tucker's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical failure Summary:

According to the available documents, Ms. Tucker has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - C3-4 disc desiccation
  - C4-5 disc desiccation, endplate degenerative changes, broad midline disc protrusion, and central canal stenosis
  - C5-6 disc desiccation, endplate degenerative changes, disc protrusion, central canal stenosis, and biforaminal uncovertebral bony hypertrophy

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury. (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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- Thoracic and Lumbar Spine
    - Sprain/strain
    - T7-T8 Shallow paracentral disc protrusion
    - Thoracic endplate degenerative changes
- Shoulder
    - Sprain/strain
- Right arm and elbow
    - Tendonitis

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Subaru Loyale in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Subaru and the Toyota, where the primary points of impact to the incident Toyota and the subject Subaru were to the front and rear, respectively.

The damage estimate of the subject Subaru Loyale indicated damage primarily to the rear bumper cover and rear bumper components; which is consistent with the reviewed photographic reproductions (Figure 1). Additionally, according to Mr. Kurek's statement, there was no noticeable damage to the incident Toyota.

Figure 1: Reproductions of photographs of the subject 1990 Subaru Loyale

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Subaru Loyale and geometric measurements of a 1990 Subaru Loyale revealed the damage due to the subject incident. A scientific analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Subaru Loyale would result in significant and visibly noticeable crush across the entire rear of the subject vehicle's rear structure, with a residual crush of 5.5 inches. Therefore, the scientific analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Subaru Loyale indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Furthermore, the Insurance Institute for Highway Safety (IIHS) tested vehicles similar to the subject vehicle, in a five mile-per-hour rear impact into a flat barrier which resulted in damage consistent with and comparable to the subject incident. Finally, Mr. Kurek's statement indicated that the incident Toyota was stopped approximately 3 to 4 feet behind the subject Subaru before pressing the accelerator at the traffic signal. At 3 feet behind, the maximum achievable speed, with full throttle and no braking, would be 7.47 mph, and at 4 feet it would be 8.62 mph.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour for the subject Subaru Loyale. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[18] By the laws of physics, the average acceleration experienced by the subject Subaru Loyale in which Ms. Tucker was seated was less than 3.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Tucker experiences 1g of loading while in a sedentary state. Therefore, Ms. Tucker experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Tucker in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Tucker testified that she is married and was self-employed as an educational consultant which required traveling to conduct trainings in many places. Additionally, she participated in kayaking, hiking, backpacking, bicycling, and swimming. Furthermore, the available documents indicated that Ms. Tucker participated in cross

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

country skiing and various household activities that included yard work, mowing the lawn, chopping and clipping bushes, picking raspberries, and loading and unloading cords of wood. Furthermore, Ms. Tucker had a 58 pound dog that she lifted. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Subaru in which Ms. Tucker was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Tucker's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According to the available documents, Ms. Tucker was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Tucker's principle direction of motion would be rearward, relative to the subject vehicle. Ms. Tucker testified that she was unaware of the impending contact and that her right arm hit the dash. Additionally, medical records indicate that Ms. Tucker's seat belt did not stop her trunk from flying forward.

The description of Ms. Tucker's response to the subject incident is inconsistent with the laws of physics. The laws of physics dictate that when the incident Toyota contacted the rear of the subject Subaru, had there been enough energy transferred to initiate motion, the Subaru would have been pushed forward causing Ms. Tucker's seat to move forward relative to her body, which would result in Ms. Tucker moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Tucker and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] The low accelerations in the subject

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19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

incident and the restraint provided by the seatback, then, were such that any motion of Ms. Tucker would have been limited to well within the range of normal physiological limits.

Findings:

1. On April 4, 2009, Ms. Laura Tucker was the restrained driver of a 1990 Subaru Loyale that was contacted in the rear at low speed by a 2007 Toyota Avalon.
2. The change in velocity was less than 10 miles-per-hour with average accelerations less than 3.0g.
3. The acceleration experienced by Ms. Tucker was within the limits of human tolerance, the personal tolerance levels of Ms. Tucker and comparable to that experienced during various daily activities.

Evaluation of Biomechanical failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Tucker was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a

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[24] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[25] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of protrusion, bulging or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[26]

Cervical Spine

According to a cervical MRI dated September 22, 2010 (approximately 17 months post-incident) there were findings consistent with degenerative changes at the C3-4, C4-5, and C5-6 levels, a broad 3 mm midline disc protrusion at the C4-5 level, and a 2 mm midline disc protrusion at the C5-6 level. Additionally, the available documents indicated that Ms. Tucker was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Subaru Loyale would be pushed forward and Ms. Tucker would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. The federal standard for seatback height specifies for a minimum height of 700mm or 27.5 inches. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Tucker's age (53 years), height (63 inches) and weight (226 lbs), Ms. Tucker has a normal seated height of 32.3 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Tucker and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failures to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected

[26] White III, A.A. and M.M. Panjabi, (1990) Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

[27] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Tucker in the subject incident. The subject incident had an average acceleration less than 3.0g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Ms. Tucker would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/biomechanical failures. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Tucker cannot be made.

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28 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

30 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

31 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" *Biomedical Sciences Instrumentation*, 42:25-30.

32 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

34 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium. (2006) 25-30.

Thoracic and Lumbar Spine

According to a thoracic MRI dated September 22, 2010 (approximately 17 months post-incident) there were findings consistent with mild multilevel endplate degenerative changes and a shallow paracentral disc protrusion at the T7-T8 level. Additionally, the available documents indicated that Ms. Tucker was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had an average acceleration less than 3.0g. Ms. Tucker's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine

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35 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

36 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

39 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

40 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

41 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. In addition, the event did not create the compression/bending loading mechanism required to cause disc conditions/biomechanical failures. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Tucker, a causal link between the subject incident and claimed lumbar biomechanical failures cannot be made.

Shoulder Biomechanical failure

There is no reason to assume that the claimed shoulder biomechanical failures are causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Subaru would be pushed forward and Ms. Tucker would have moved rearward relative to the vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of both her shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Tucker's body away from the seatback.[45] Any rebound that may have occurred would have been limited by the available restraint system. Any load acting on the shoulder area due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause shoulder trauma or biomechanical failure to either shoulder. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Tucker shoulders would have been limited to well within the range of normal physiological limits.

The subject incident had an average acceleration level that was less than 3.0g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported. [46,47,48,49,50] Previous research has shown that shoulder loads during activities of daily

[42] Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[43] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

[44] Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

[45] Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

[46] Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[51,52,53,54] As a result, Ms. Tucker's shoulders would not have been exposed to any loading forces outside her personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce trauma to either shoulder. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Ms. Tucker would tend to move rearward relative to her vehicle. She would not have contacted her shoulders on any rigid interior object. There was no bruising, laceration, or abrasions associated with interaction of the vehicle interior in the subject incident. For these reasons, a causal link between the subject incident and the shoulder biomechanical failures claimed by Ms. Tucker cannot be made.

Right arm and elbow

According to the available documents, Ms. Tucker attributed her right arm and elbow tendinitis to the subject incident. There is no reason to assume that the claimed right arm and elbow biomechanical failures are causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Subaru would be pushed forward and Ms. Tucker would have moved rearward relative to the vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of her arm and elbow and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Tucker's body away from the seatback.[55] Any rebound that may have occurred would have been limited by the available restraint system. Any load acting on the arm and elbow due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any arm and elbow loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause arm and elbow trauma or biomechanical failure. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Tucker's arm and elbow would have been limited to well within the range of normal physiological limits. For these reasons, a causal link between the subject incident and the right arm and elbow biomechanical failures claimed by Ms. Tucker cannot be made.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

48 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

49 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

50 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

51 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

52 Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

53 Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

54 Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

55 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

The subject incident had an average acceleration level that was less 3.0g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported.[56,57,58,59,60] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[61,62,63,64] As a result, Ms. Tucker's shoulder would not have been exposed to any loading forces outside her personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce trauma to the right arm and elbow. The loading and kinematics of this body part was well within the limits of human tolerance and physiological motion. She would not have contacted her right arm and elbow on any rigid interior object. For these reasons, a causal link between the subject incident and the right arm and elbow biomechanical failure claimed cannot be made.

Personal Tolerance Values

According to the available documents, prior to the subject incident Ms. Tucker was noted to exercise and participate in physical activities. After the subject incident Ms. Tucker participated in range of motion studies for diagnostic purposes. These activities were performed without biomechanical failure. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Tucker and produce comparable, if not greater, forces applied to the right arm, shoulder, cervical, thoracic, and lumbar spine.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On April 4, 2009, Ms. Laura Tucker was the restrained right front passenger of a 1990 Subaru Loyale that was contacted in the rear at low speed by a 2007 Toyota Avalon.

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56 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts. (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

57 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

58 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

59 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

60 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

61 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." *Journal of Biomechanics*, In Press.

62 Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." *Clinical Biomechanics*, 19:586-594.

63 Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

64 Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." *Journal of Biomechanics*, 40:2139-2149.

2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour with an average acceleration less than 3.0g for the subject 1990 Subaru Loyale in which Ms. Tucker was seated.
3. The acceleration experienced by Ms. Tucker's was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Tucker's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Tucker's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Tucker's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Tucker's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Tucker's claimed right arm and elbow biomechanical failures. As such, a causal relationship between the subject incident and the right arm and elbow biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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January 22, 2013

Mark Dietzler, Esquire
Law Offices of Kelley J. Sweeney
1191 2nd Avenue, Suite 500
Seattle, WA 98101

RECEIVED
By
FEB 05 2013
Law Offices of
Kelley J. Sweeney

Re: *White, Richard v. Liberty Northwest*
Claim No. A0891714
ARCCA Case No.: 3271-217

Dear Mr. Dietzler:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Richard White. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D.. (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions. (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

ARCCA

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on November 7, 2008, Mr. Richard White was the restrained driver of a 2001 Ford Explorer Sport Trac traveling northbound on Kitsap Way near the State Route 3 entrance in Bremerton, Washington. Ms. Nicole Hafner was the driver of a 2004 Nissan Sentra traveling on Kitsap Way directly behind the Ford. According to the available documents, the Ford stopped at a crosswalk for pedestrians and the Nissan failed to stop in time. As a result, the front of the incident Nissan contacted the rear of the subject Ford. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eight (8) color photographic reproductions of the subject 2001 Ford Explorer Sport Trac
- Twelve (12) color photographic reproductions of the incident 2004 Nissan Sentra
- Uptown Auto Body Rebuild, Inc. Supplement of Record 1 with Summary for the subject 2001 Ford Explorer Sport Trac [November 13, 2008]
- Uptown Auto Body Rebuild, Inc. repair estimate for the incident 2004 Nissan Sentra [November 18, 2008]
- Respondent's First Interrogatories and Requests for Production of Documents to Plaintiff, *Richard White vs. Liberty Northwest* [July 2012]
- Medical Records pertaining to Richard White
- VinLink data sheet for the subject 2001 Ford Explorer Sport Trac
- Expert AutoStats data sheets for a 2001 Ford Explorer Sport Trac
- VinLink data sheet for the incident 2004 Nissan Sentra
- Expert AutoStats data sheets for a 2004 Nissan Sentra

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M. (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

ARCCA

1. Identify the biomechanical failures that Mr. White claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. White was occupying;
3. Determine Mr. White's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Mr. White's response to the subject incident.
5. Evaluate Mr. White's personal tolerance in the context of their pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Mr. White has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Left Shoulder
  - Multiple biceps tendon tears and glenoid labrum biomechanical failure

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Ford Explorer Sport Trac and incident Nissan Sentra in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Ford and the Nissan, where the primary points of impact to the incident Nissan and the subject Ford were to the front and rear, respectively.

The damage estimate of the subject Ford Explorer Sport Trac indicated damage primarily to the rear bumper cover, impact bar, left and right impact bar bracket, left and right impact bar arm, left and right step pad, hitch plate, and rear rails at mounting brackets; which is consistent with

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2: 55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3: 27-55.

[10] Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

the reviewed photographic reproductions (Figure 1). The damage estimate of the incident Nissan Sentra indicated damage primarily to the front bumper cover, energy absorber, upper retainer, right retaining bracket, right stay bracket, grille assembly, left and right headlamp assembly, radiator support, hood, right fender, and right front wheel cover; which is consistent with the reviewed photographic reproductions (Figure 2).

Figure 1: Reproductions of the subject 2001 Ford Explorer Sport Trac

Figure 2: Reproductions of the incident 2004 Nissan Sentra

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Nissan can be used to resolve the loads sustained by the subject Ford. That is, the loads sustained by the incident Nissan are equal and opposite to those of the subject Ford.

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Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the incident Nissan Sentra and geometric measurements of a 2004 Nissan Sentra revealed the damage due to the subject incident. An energy-based crush analysis[16] indicates that a single 10-mile-per-hour barrier impact to the front of a Nissan Sentra would result in significant and visibly noticeable crush across the entirety of the subject vehicle's front structure, with a residual crush of 3.5 inches. Therefore, the energy-based crush analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the front of the subject Nissan Sentra indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour for the incident Nissan (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity). Additionally, the above analysis is consistent with an energy-based crush analysis of a 2001 Ford Explorer Sport Trac.

Review of the vehicle damage, incident data, published literature, scientific analyses, conservation of momentum and my experience indicates an incident resulting in a Delta-V of less than 6.4 miles-per-hour for the subject Ford Explorer Sport Trac. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.4-mile-per-hour impact is 1.9g.[18] By the laws of physics, the average acceleration experienced by the subject Ford Explorer Sport Trac in which Mr. White was seated was less than 1.9g.

The acceleration experienced due to gravity is 1g. This means that Mr. White experiences 1g of loading while in a sedentary state. Therefore, Mr. White experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by either occupant in his daily life would have increased the loading to his body beyond the sedentary 1g. According to the available documents, Mr. White had a desk job with the Department of Veteran Affairs and worked in residential remodeling. While remodeling properties, Mr. White would use ladders, paint, and conduct the remodeling work himself. Additionally, Mr. White participated in skiing, golfing kayaking, crabbing, and motorcycle riding. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's

11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of frontal crashes in terms of average acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance. The energy imparted to the Ford in which Mr. White was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Mr. White's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According to the available documents, Mr. White was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Mr. White's principle direction of motion would be rearward, relative to his vehicle. Additionally, the documents indicate Mr. White did not strike his head during the subject incident.

The laws of physics dictate that when the incident Nissan Sentra contacted the rear of the subject Ford Explorer Sport Trac, had there been enough energy transferred to initiate motion, the Ford would have been pushed forward causing Mr. White's seat to move forward relative to his body, which would result in Mr. White moving rearward relative to the interior of the subject vehicle. This interaction between Mr. White and the subject vehicle's interior would cause his body to load into the seatback structures. Specifically, his torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. White would have been limited to well within the range of normal physiological limits.

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19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42: 25-30.

21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

Findings:

1. On November 7, 2008, Mr. Richard White was the belted driver of a 2001 Ford Explorer Sport Trac that was contacted in the rear at low speed.
2. The change in velocity was less than 6.4 miles-per-hour with average accelerations below 1.9g.
3. The acceleration experienced by Mr. White was within the limits of human tolerance, the personal tolerance levels of Mr. White and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. White was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no reason to expect the presence of an biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

[24] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[25] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

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Cervical Spine
According to the available documents, Mr. White was diagnosed with a cervical sprain/strain.

In a rear impact that produces motion of the subject vehicle, the Dodge would be pushed forward and Mr. White would have moved rearward relative to the vehicle, until his motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck.

Examination of an exemplar 2001 Ford Explorer Sport Trac showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 29.0 inches. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Mr. White's age (57 years), height (71 inches) and weight (235 lbs), Mr. White has a normal seated height of 35.6 inches. Thus the seat may have allowed for some extension of Mr. White however, one would not expect hyperextension due to the minor nature of the subject incident and would not see any biomechanical failures greater than transient neck stiffness and soreness.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Mr. White in the subject incident. The subject incident had an average acceleration less than 1.9g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[28] Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal* 6:366-375.

[29] Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine* 29:979-987.

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greater than the accelerations associated with the subject incident.[30,31] Mr. White would not have been exposed to any loading or motion outside of his personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As previously stated, Mr. White may have experienced some hyperextension of his cervical spine however; one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness.

Thoracic Spine

According to the available documents, Mr. White was diagnosed with a thoracic sprain/strain.

There is no reason to assume that the claimed thoracic spine biomechanical failures are causally related to the subject incident. In a rear impact the pelvis, thoracic and lumbar spine of an occupant are well supported by the seat and seatback. The seatback structures prevent injurious motions or loading of the thoracic and lumbar spine. Thus, the seatback would limit the range of motion to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the upper body. The seatback would not allow for hyperextension of Mr. White's thoracic spine. An occupant's body reacts as a whole, meaning the back moves as a whole unit rearward with no extension, unless one portion of the spine is supported with another portion unsupported. As a result of the subject incident, the occupant's torso and pelvis would settle back into the seatback structures. The low accelerations resulting from this collision would have caused little, or no, forward rebound of Mr. White's body away from the seat back.[34,35,36] Any rebound would have been within the range of protection afforded by the available restraint system and significant loading to Mr. White's thoracic and lumbar spine would not be expected.

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30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42: 25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

34 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

35 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

36 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1): 55-66.

As mentioned before, Ng et al. measured accelerations of the head and spinal structures during activities of daily living. [37,38] Accelerations of the thoracic and lumbar spines were measured during activities of daily living, and peak accelerations were measured to be an average 5.09g for small females (averaging 1.58 meters in height) and average 4.24g for medium females (averaging 1.65 meters in height) for sitting quickly in a chair. In some of the tests, the peak accelerations for quickly sitting in a chair were over 7g in small and medium females. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender).

Live human subjects' torsos have regularly been exposed to rear g-levels up to approximately 40g with no acute trauma during rear impacts.[39] The subject incident had average accelerations below 1.9g. Mr. White's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[40]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with thoracic spine. The forces created by the incident were well within the limits of human tolerance for thoracic and lumbar strength and were within the range typically seen in normal, daily activities. For these reasons, a causal link between the subject incident and the thoracic spine biomechanical failures claimed by Mr. White cannot be made. It should be noted that eccentric exercise can create delayed onset muscle soreness. This is not an injury but is caused by disruption of sarcomeres within the muscle fibers. It is not uncommon for muscles to become sore after unaccustomed exercise, but again, this is not a biomechanical failure.

Left Shoulder

According to an operative report of Mr. White's left shoulder, dated March 23, 2011, there were findings consistent with multiple longitudinal tears in the biceps tendon. Additionally, the report indicated findings of a total absence of the anterior inferior glenoid labrum and that a Bankart repair along with open bicep tenodesis was performed.

There is no reason to assume that the claimed left shoulder biomechanical failure is causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Ford would be pushed forward and Mr. White would have moved rearward relative to the vehicle, until his motion was halted by the seatback. This interaction with the seatback would both limit the motion of both his shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Mr. White's body away from the seatback.[41] Any rebound that

37 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

38 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

39 Weiss. M.S., Lustick. L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

40 Gushue, D., Probst, B., et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

41 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

may have occurred would have been limited by the available restraint system. Any load acting on the shoulder area due to restraint forces would have been dispersed over the respective occupant's torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause shoulder trauma or biomechanical failure to his left shoulder. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Mr. White's left shoulder would have been limited to well within the range of normal physiological limits.

Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The rotator cuff is the group of muscles responsible for holding the head of the humerus firmly in the shoulder socket, stabilizing the shoulder joint and allowing for movements of the upper arm.

Furthermore, the subject incident lacks the physical mechanism to produce trauma to the biceps tendon of the left shoulder. The biceps tendon runs along the anterior aspect of the upper arm and inserts into the scapula.[42] Therefore, acute tearing to the biceps tendon requires sudden force application to the biceps that exceeds physiologic limits.[43,44,45] The primary function of the biceps is to flex the elbow. The biomechanical failure mechanism required for a labrum tear involves loading directed into the glenoid fossa that generates a shearing force between the humeral head and glenoid labrum.[46,47,48] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[49] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The shoulder joint is commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15] Additionally, rotator cuff tears are frequently coupled with a chronic mechanism with degenerative etiologies.[50,51,52] The subject event

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42 Bicos J., (2008) "Biomechanics and Anatomy of the Proximal Biceps Tendon." Sports Medicine and Arthroscopy Review. 16(3): 111-117.

43 Miller, K.E., and Solomon, D.J., (2008) "Paralabral Rupture of the Proximal Biceps Tendon from Light Weightlifting." Military Medicine 173 (12): 1238-1240.

44 Bain, G.I., Johnson, L.J., and Turner, P.C., (2008) "Treatment of Partial Distal Biceps Tendon Tears." Sports Medicine and Arthroscopy Review. 16(3): 154-161.

45 Friedman, D.J., Dunn, J.C., Higgins, L.D., et al., (2008) "Proximal Biceps Tendon: Injuries and Management." Sports Medicine and Arthroscopy Review. 16(3): 162-169.

46 D'Alessandro, D.F., Fleischli, E., et al., (2000) "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.

47 Payne, L. Z., (1994) "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.

48 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008) "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.

49 Moore, K.L. and Dalley, A.F., (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

50 Ozaki, et al., (1988) Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. A study in cadavera. The Journal of Bone and Joint Surgery, 70 (8), 1224-1230.

51 Whiting, W. C. and Zernicke, R.F., (2008) Biomechanics of musculoskeletal injury. Human Kinetics, Champaign, IL.

52 Burkhead, W.Z., (1996) Rotator cuff disorders. Williams & Wilkins, Baltimore.

did not create the loading mechanism required to cause biomechanical failure to the left biceps tendon or labrum.

The subject incident had an average acceleration level that was less than 1.9g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported. [53,54,55,56,57] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[58,59,60,61] As previously stated, Mr. White remodeled properties on a regular basis which required him to lift heavy objects, reach and constantly load his shoulders. As a result, Mr. White's left shoulder would not have been exposed to any loading forces outside his personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce trauma to the left shoulder. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Mr. White would tend to move rearward relative to his vehicle. He would not have contacted his right or left shoulder on any rigid interior object. There was no bruising, laceration, or abrasions associated with interaction of the vehicle interior in the subject incident. For these reasons, a causal link between the subject incident and the left shoulder biomechanical failures claimed by Mr. White cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents Mr. White was involved in remodeling properties. Mr. White would use ladders, paint, and conduct the remodeling work himself. Additionally, Mr. White participated in skiing, golfing kayaking, crabbing, and motorcycle riding.. These activities were performed without biomechanical failure. These activities can produce greater movement, or stretch, to the soft tissues of Mr. White and produce comparable, if not greater, forces applied to the left shoulder, cervical, thoracic, and lumbar spine.

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53 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

54 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

55 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

56 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

57 Castro, W.H.M., Schilgen, M., Meyer, S., Weber, M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

58 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

59 Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

60 Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

61 Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

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Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 7, 2008, Mr. Richard White was the belted driver of a 2001 Ford Explorer Sport Trac that was contacted in the rear at low speed.
2. The severity of the subject incident was consistent with a Delta-V below 6.4 miles-per-hour with an average acceleration below 1.9g for the subject 2001 Ford Explorer Sport Trac in which Mr. White was seated.
3. The acceleration experienced by Mr. White was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. White's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits
5. There is no biomechanical failure mechanism in the subject incident for Mr. White's claimed cervical spine biomechanical failures. As such, a causal relationship between the subject incident and the cervical spine biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism in the subject incident for Mr. White's claimed thoracic spine biomechanical failures. As such, a causal relationship between the subject incident and the thoracic spine biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism in the subject incident for Mr. White's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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May 22, 2013

Ryan Aslakson
Safeco Insurance Company
P.O. Box 515097
Los Angeles, CA 90051-9803

Re: *Stark, Jasmine v. Jijun Lu*
Claim No.: 304348114008
ARCCA Case No.: 3271-204

Dear Mr. Aslakson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Jasmine Stark. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomedical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on September 23, 2009, Ms. Jasmine Stark was the seat belted driver of a 1998 Honda CRV traveling northbound on Interstate 405 near State Route 181 in Renton, Washington. Mr. Jijun Lu was the seat belted driver of a 2009 Ford Escape traveling on Interstate 405 directly behind the Honda. According to the available documents, the Honda slowed for traffic and was struck from behind by the incident Ford. As a result, the front of the incident Ford contacted the rear of the subject Honda. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. E027875
- Nineteen (19) color photographic reproductions of the subject 1998 Honda CRV
- Six (6) color photographic reproductions of the incident 2009 Ford Escape
- Thoroughbred Collision Center – West Seattle repair estimate for the subject 1998 Honda CRV [September 25, 2009]
- Burien Honda Body Shop Preliminary Supplement 1 with Summary for the subject 1998 Honda CRV [September 29, 2009]
- Safeco Insurance Company of Illinois Supplement 1 with Summary for the subject 1998 Honda CRV [October 1, 2009]
- First National Insurance Company of America repair estimate for the incident 2009 Ford Escape [September 28, 2009]
- First National Insurance Company of America Supplement of Record 1 with Summary for the incident 2009 Ford Escape [October 5, 2009]
- First National Insurance Company of America Supplement of Record 2 with Summary for the incident 2009 Ford Escape [January 4, 2010]
- First National Insurance Company of America Supplement of Record 3 with Summary for the incident 2009 Ford Escape [February 9, 2010]
- Auto Nation Collision Center – Seattle Supplement or Record 2 with Summary for the incident 2009 Ford Escape [December 21, 2009]
- Auto Nation Collision Center – Seattle Preliminary Supplement 4 with Summary for the incident 2009 Ford Escape [December 15, 2009]
- Auto Nation Collision Center – Seattle Preliminary Supplement 5 with Summary for the incident 2009 Ford Escape [February 8, 2010]

- Medical Records pertaining to Jasmine Stark
- VinLink data sheet for the subject 1998 Honda CRV
- Expert AutoStats data sheets for a 1998 Honda CRV
- VinLink data sheet for the incident 2009 Ford Escape
- Expert AutoStats data sheets for a 2009 Ford Escape

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Stark claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Stark was occupying;
3. Determine Ms. Stark's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Stark's response to the subject incident;
5. Evaluate Ms. Stark's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Biomechanical Failure Summary:

According to the available documents, Ms. Stark has reported the following biomechanical failures as a result of the subject incident:

- Right Plantar Fasciitis

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Honda CRV and incident Ford Escape in association with accepted methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Ford, where the primary points of impact to the incident Ford and the subject Honda were to the front and rear, respectively.

The damage estimate of the subject Honda CRV indicated damage primarily to the rear door, spare cover, rear spare bracket, rear bumper cover, rear body panel, rear floor pan, tow hitch, frame set up and pull to rear floor pan and body panel; which is consistent with the reviewed photographic reproduction (Figure 1).

Figure 1: Reproductions of photographs of the subject 1998 Honda CRV

The damage estimate of the incident Ford Escape indicated damage primarily to the front bumper cover, right front bumper cover brace, reinforcement, license bracket, right bumper cover bracket, grille reinforcement, grille, left and right headlamp assembly, upper tie bar, headlamp center support, left and right upper tie bar support, radiator, fan assembly, dehydrator, AC

condenser, hood, hood latch, left and right hinge, left and right fender, right upper rail, right rail reinforcement, and right lower rail assembly; which is consistent with the reviewed photographic reproduction (Figure 2).

Figure 2: Reproductions of photographs of the subject 2009 Ford Escape

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Honda CRV and geometric measurements of a 1998 Honda CRV revealed the damage due to the subject incident. A scientific analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Honda CRV would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 4.75 inches. Therefore, the analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Honda indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V of less than 10 miles-per-hour for the subject Honda CRV. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[18] By the laws of physics, the average acceleration experienced by the subject Honda in which Ms. Stark was seated was less than 3.0g.

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of frontal crashes in terms of average acceleration, (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Ms. Stark experiences 1g of loading while in a sedentary state. Therefore, Ms. Stark experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Stark in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, Ms. Stark was a very active individual that participated in sailing, snorkeling, swimming, hiking, skiing, gardening and dancing. Additionally, the records indicated that Ms. Stark ran, performed Pilates and strength trained. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Honda CRV in which Ms. Stark was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Stark's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According to the State of Washington Police Traffic Collision Report and other available documents, Ms. Stark was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Stark's principle direction of motion would be rearward, relative to the subject vehicle. Additionally, the documents indicate Ms. Stark was bracing herself on the floor and braking with her right foot.

The laws of physics dictate that when the incident Ford Escape contacted the rear of the subject Honda CRV, had there been enough energy transferred to initiate motion, the Honda would have been pushed forward causing Ms. Stark's seat to move forward relative to her body, which would result in Ms. Stark moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Stark and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward

[19] Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

[20] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

rebound of her body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Stark would have been limited to well within the range of normal physiological limits.

Findings:

1. On September 23, 2009, Ms. Jasmine Stark was the seat belted driver of a 1998 Honda CRV that was contacted in the rear at low speed by a 2009 Ford Escape.
2. The change in velocity was less than 10 miles-per-hour with average accelerations less than 3.0g.
3. The acceleration experienced by Ms. Stark was within the limits of human tolerance, the personal tolerance levels of Ms. Stark and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Stark was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Right Plantar Fasciitis

According to the available documents, Ms. Stark was diagnosed with right foot plantar fasciits. A foot exam dated June 22, 2011 revealed Ms. Stark had gastric tightness bilaterally, a cavus foot and her foot shows hallmark signs of gastrocnemius tightness and cavus feet with some bossing of her talus and arthritic changes.

The plantar fascia is dense band of fibers that maintains the longitudinal arch of one's foot. The plantar fascia also assists with the absorption/adaptation to ground shock and ground abnormalities while walking, running, etc. The plantar fascia originates mainly from the medial calcaneal tuberosity on the inferior side of the calcaneus and inserts at several points into the plantar plates of the metatarso-phalangeal joints. Plantar fasciitis is thought to be caused by microtears in the plantar fascia fibers near the heel; which results in inflammation and pain. More recent studies have shown the condition is degenerative in nature from the mircotears rather than directly inflammatory. Plantar fasciitis is most commonly found in middle-aged women and runners. Plantar fasciitis is occurs due to prolonged standing and running which causes overuse and results in the microtears.[26,27,28]

As previously stated, the available documents indicated Ms. Stark was bracing herself on the floor and braking with her right foot. Due to the subject impact, Ms. Stark's seat would have moved forward relative to her body, which would result in Ms. Stark moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Stark and the subject vehicle's interior would cause her body to load into the seatback structures and move away from the subject vehicle pedals and floor. Additionally, studies have shown that when subjects are aware of an impending impact, they move rearward and disengage from the brake pedal. The peak force recorded during hard braking was approximately 1246N with an average brake pedal force of approximately 700N.[29] Comparatively, walking and running produces peak forces upwards of 1500N with an average impact force of approximately 1100N. Additionally, stumbling, single leg hopping and jumping has been shown to have comparable and greater impact forces on the body.[30,31,32,33,34,35]

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26 Young, C., et al., (2012) "In the Clinic: Plantar Fasciitis." *Annals of Internal Medicine,* ITC1-16.

27 Singh, D., Angel, J., Bentley, G., Trevino, S.G., (1997) "Fortnightly Review: Plantar Fasciitis." *British Medical Journal,* 315:172-175.

28 Goff, J.D, Crawford, R., (2011) "Diagnosis and Treatment of Plantar Fasciitis." *American Family Physician,* 84(6): 676-682.

29 Ivory, M.A., Furbish, C., et al., (2010) Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions (SAE 2010-01-0067). Warrendale, PA, Society of Automotive Engineers.

30 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

31 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

32 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

33 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

34 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

There is no reason to assume that the claimed right plantar fasciitis is causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and Ms. Stark would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. During this motion, Ms. Stark's feet would have moved away from the floor and pedals. As such, the subject incident did not generate the biomechanical failure mechanisms required to cause Ms. Stark's right plantar fasciitis biomechanical failures.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On September 23, 2009, Ms. Jasmine Stark was the seat belted driver of a 1998 Honda CRV that was contacted in the rear at low speed by a 2009 Ford Escape.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles-per-hour with an average acceleration less than 3.0g for the subject 1998 Honda CRV in which Ms. Stark was seated.
3. The acceleration experienced by Ms. Stark was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Stark's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Stark's claimed right plantar fasciits biomechanical failure. As such, a causal relationship between the subject incident and the right plantar fasciits biomechanical failure cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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[35] Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

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4314 ROOSEVELT WAY NE
SEATTLE, WA 98105
PHONE 877-942-7222 FAX 206-547-0759
www.arcca.com

EXHIBIT
Probst 30
5-22-17 MY

June 10, 2013

Mark W. Conforti, Esquire
Dynan Conforti, P.S.
2102 North Pearl Street
Suite 400, Building D
Tacoma, WA 98406-2550

Re: *Hughes, Rebecca M., vs. Nadezhda Krykun*
Claim No.: 331-035395
Snohomish County Superior Court No. 12-2-06817-6
Your File No.: 12-6013
ARCCA Case No.: 4404-001

Dear Mr. Conforti:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Rebecca Hughes. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

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3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

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5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

A police incident report for the subject incident was not available. Therefore, the following incident description is based upon the reviewed documents. On June 9, 2011, Ms. Rebecca Hughes was the seat belted driver of a 1994 Toyota Corolla traveling southbound on State Route 99 in Lynnwood, Washington. The Hughes vehicle was stopped at the intersection of 196th Street SW waiting to make a left turn. Ms. Nadezhda Krykun was the seat belted driver of a 2006 Honda Accord behind the subject Toyota. Ms. Krykun failed to stop her vehicle in time and as a result, the front of the incident Honda contacted the rear of the subject Toyota. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Ten (10) color photographic reproductions of the subject 1994 Toyota Corolla
- Deposition Transcript of Rebecca Hughes [April 16, 2013]
- Medical Records pertaining to Rebecca Hughes
- Defendant's First Interrogatories And Requests For Production To Plaintiff, Rebecca M. Hughes With Answers And Responses Thereto
- Complaint
- American Family Mutual Insurance Company Estimate for the subject Toyota Corolla appraised by John C. Davis [June 16, 2011]
- VinLink data sheet for the subject 1994 Toyota Corolla
- Expert AutoStats data sheets for a 1994 Toyota Corolla
- VinLink data sheet for the incident 2006 Honda Accord
- Expert AutoStats data sheets for a 2006 Honda Accord
- Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report for a 2003 Honda Accord
- Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report for a 2007 Honda Accord
- ARCCA inspection of the incident Honda Accord, May 22, 2013

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation

ARCCA

as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Hughes claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Hughes was occupying;
3. Determine Ms. Hughes's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Hughes's response to the subject incident;
5. Evaluate Ms. Hughes's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical failure Summary:

According to the available documents, Ms. Hughes has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Cervicalgia
- Thoracic Spine
  - Sprain/strain
  - Thoracic segmental dysfunction
- Lumbar Spine
  - Lumbar segmental dysfunction
  - Lumbago
- Bilateral Wrist
  - Sprain/strain

6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota Corolla and incident Honda Accord in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Honda and the Toyota, where the primary points of impact to the incident Honda and the subject Toyota were to the front and rear respectively.

The photographic reproductions of the subject Toyota Corolla depicted cosmetic damage. This is confirmed in the repair estimate that notes only damage to the rear bumper cover. The inspection of the incident Honda Accord noted only cosmetic damage to the front bumper cover.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and the repair estimate of the subject Toyota Corolla and geometric measurements of a 1994 Toyota Corolla revealed the damage due to the subject incident. An energy-based crush analysis[16] indicates that a single 10-mile-per-hour barrier impact to the rear of a Toyota Corolla would result in significant and visibly noticeable crush across the entirety of the subject vehicle's rear structure, with a residual crush of 4.75 inches. Therefore, the scientific analysis shows significantly greater deformation would occur in a 10-mile-per-hour Delta-V impact than that of the subject incident.[17] The lack of significant structural crush to the rear of the subject Toyota indicates that the subject incident is consistent with a collision resulting in a Delta-V less than 10 miles per hour (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. This empirical testing was used to perform a damage threshold speed change analysis.[18] The IIHS tested several cars of the same era from the same manufacturer as the subject vehicle as well as vehicles from other manufacturers. In a five mile-per-hour rear impact into a flat barrier the test vehicles sustained damage to the rear bumper covers, rear reinforcement bars, and rear mounting brackets among other parts in some tests. The primary damage to the subject Toyota was to the rear bumper cover and rear body panel. Thus, because the test vehicles in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is more comparable to the severity of the subject incident and places the subject incident speed closer to the test speed of 5 miles-per-hour.

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers

Finally, the Insurance Institute for Highway Safety (IIHS) performed low-speed tests on both a 2003 and 2007 Honda Accord, essentially the same vehicles as the 2006 Honda Accord. In a 5 mile-per-hour front impact into a flat barrier, the test Honda sustained damage to the front bumper cover, energy absorber, and reinforcement bar. In a 3.1 mile-per-hour front corner impact into a flat barrier, the test Honda sustained damage to the front bumper cover, front bumper cover support, headlamp assembly and front fender. The primary damage to the incident Honda was to the transfer of bumper sticker material to the front bumper cover on the driver's side. Thus, because the test Honda Accord in the IIHS front corner impact test sustained comparable if not greater damage, the severity and energy transfer of the IIHS impact is consistent with the severity of the subject incident and places the subject incident consistent with the test speed of 3.1 miles-per-hour.

Review of the vehicle damage, incident data, published literature, scientific analyses, the conservation of momentum and my experience indicates an incident resulting in a Delta-V comparable to 3.1 miles-per-hour for the subject Toyota Corolla. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the peak acceleration associated with a 3.1 mile-per-hour impact is 1.4g.[19] By the laws of physics, the peak acceleration experienced by the subject Toyota Corolla in which Ms. Hughes was seated less than 1.4g.

The acceleration experienced due to gravity is 1g. This means that Ms. Hughes experiences 1g of loading while in a sedentary state. Therefore, Ms. Hughes experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Hughes in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Hughes noted that she could perform household chores such as sweeping and cooking, as well as playing with children. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[21]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota Corolla in which Ms. Hughes was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not

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19 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

20 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

21 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

expect a biomechanical failure mechanism for Ms. Hughes's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According her testimony, Ms. Hughes was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Hughes's principle direction of motion would be rearward, relative to the subject vehicle. The laws of physics dictate that when the incident Honda contacted the rear of the subject Toyota, had there been enough energy transferred to initiate motion, the Toyota would have been pushed forward causing Ms. Hughes's seat to move forward relative to her body, which would result in Ms. Hughes moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Hughes and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[22,23,24] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Hughes would have been limited to well within the range of normal physiological limits.

Findings:

1. On June 9, 2011, Ms. Rebecca Hughes was the seat belted driver of a 1994 Toyota Corolla that was contacted in the rear at low speed by a 2006 Honda Accord.
2. The change in velocity comparable to 3.1 miles-per-hour with peak acceleration of 1.4g.
3. The acceleration experienced by Ms. Hughes was within the limits of human tolerance, the personal tolerance levels of Ms. Hughes and comparable to that experienced during various daily activities.

Evaluation of Biomechanical failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Hughes was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[25,26]

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22 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

23 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

24 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

25 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If an biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda would be pushed forward and Ms. Hughes would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, approximately 4 inches below the top of the head, as this is the area of the center of rotation of the skull. Examination of an exemplar 1993 Toyota Corolla, essentially the same vehicle as the 1994 Toyota Corolla showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 28.25 inches with the head restraint in the full down position and 31.5 inches in the full up position. This does not account for seat compression; the seat bottom cushion will compress approximately two to three inches with an occupant of Ms. Hughes's habitus. Based on an anthropometric regression of Ms. Hughes's age (60 years), height (63.5 inches) and weight (223 lbs), Ms. Hughes would have a normal seated height of 32.4 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Hughes and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failures to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[27] The only

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[26] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

[27] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[28] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[29] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[30] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Hughes in the subject incident. The subject incident had a peak acceleration less than 1.4g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31,32] Ms. Hughes would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[33,34] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities.

Thoracic and Lumbar

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or

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28 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

29 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

30 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

31 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

32 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

34 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic, lumbar, or sacral spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic, lumbar, or sacral spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[35] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[36] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[37] The subject incident had a peak acceleration less than 1.4g. Ms. Hughes's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[38,39,40,41,42] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical

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35 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

36 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

39 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

40 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

41 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

42 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

43 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities.

Bilateral Wrist

There is no reason to assume that the claimed bilateral wrist biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota would be pushed forward and Ms. Hughes would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. Furthermore, as previously stated Ms. Hughes's body would have moved rearward and the interaction with the seatback and her body would have minimized her motion. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Hughes's body away from the seatback.[45] Any rebound that may have occurred would have been limited by the available restraint system. Any load acting on the upper extremities due to restraint forces would have been dispersed over her torso and pelvis, thereby minimizing any upper extremity loads. As a result, the subject incident did not create any of the injury mechanisms necessary to cause injury to either of her shoulders, elbows, wrists or hands.

The subject incident had a peak acceleration level that was consistent with 1.4g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no upper extremity injuries were reported.[46,47,48,49,50] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[51,52,53,54] As a result, Ms. Hughes wrists would not have been exposed to any loading forces outside her personal tolerance range.

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44 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

45 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

46 Szabo, T.J., J.B. Welcher, et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997) Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles, (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

48 West, D.H., J.P. Gough, et al. (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

49 Braun, T.A., Jhoun, J.H., Braun, M.J., et al., (2001) Rear-end Impact Testing with Human Test Subjects, (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

50 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

51 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

52 Murray, I.A., and Johnson, G.R., (2004) "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19:586-594.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Hughes's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Hughes using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On June 9, 2011, Ms. Rebecca Hughes was the seat belted driver of a 1994 Toyota Corolla that was contacted in the rear at low speed by a 2006 Honda Accord.
2. The severity of the subject incident was consistent with a Delta-V comparable to 3.1 miles-per-hour with peak acceleration of 1.4g for the subject Honda Accord in which Ms. Hughes was seated.
3. The acceleration experienced by Ms. Hughes was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Hughes's body rearward. These motions would have been limited and well controlled by the seat structures and seatbelt restraint. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hughes's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hughes's claimed thoracic or lumbar spine biomechanical failures. As such, a causal relationship between the subject incident and the thoracic or lumbar spine biomechanical failures cannot be made
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hughes's claimed bilateral wrist biomechanical failures. As such, a causal relationship between the subject incident and the bilateral wrist biomechanical failures cannot be made.

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[53] Anglin, C., Wyss, U.P., and Pichora, D.R., (1997) "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

[54] Bergmann, G., Graichen, F., Bender, A., et al., (2007) "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40:2139-2149.

ARCCA

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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EXHIBIT
Probst 31
5-23-17

June 14, 2013

Mark Hiefield, Esquire
Hiefield, Foster & Glascock, LLP
6915 SW Macadam Avenue
Suite 300
Portland, OR 97219

Re: *Johnson, Victoria v. Susan Ginther*
ARCCA Case No.: 3666-041

Dear Mr. Hiefield:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanics involved in the incident of Victoria Johnson. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanics.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical effect.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

Incident Description:

According to the State of Washington Police Traffic Collision Report and other available documents, on May 15, 2012, Ms. Victoria Johnson was the restrained driver of a 2006 Toyota Corolla traveling northbound on NE 137th Avenue near NE 76th Street in Vancouver, Washington. Mr. Robert Lecomte was the driver of a 2007 Jeep Grand Cherokee traveling directly behind the Toyota. Ms. Susan Ginther was the driver of a 2005 Chrysler Pacifica traveling directly behind the Jeep. According to the available documents, the subject Toyota, incident Jeep, and incident Chrysler were stopped for a red traffic signal. While waiting for the traffic signal to turn green, the incident Chrysler proceeded forward and struck the rear of the incident Jeep. Subsequently, the incident Jeep was pushed forward and struck the rear of the subject Toyota. The subject Toyota was driven from the scene and the airbags did not deploy.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report [May 15, 2012]
- Eight (8) color photographic reproductions of the subject 2006 Toyota Corolla
- Twenty (20) color photographic reproductions of the incident 2005 Chrysler Pacifica
- Twenty-eight (28) color photographic reproductions of the incident 2007 Jeep Grand Cherokee
- Todd's Auto Body, Inc. – Estimate for the subject 2006 Toyota Corolla [May 25, 2012]
- Kadel's Cascade Auto Body – Preliminary Estimate for the subject 2006 Toyota Corolla [May 25, 2012]
- Brady's Auto Body, Inc. – Preliminary Estimate for the subject 2006 Toyota Corolla [May 29, 2012]
- Alliance Claims Solutions – Estimate for the subject 2006 Toyota Corolla [July 2, 2012]
- Pacific Northwest Appraisal Services – Estimate for the incident 2005 Chrysler Pacifica [May 22, 2012]
- Alliance Claims Solutions – Estimate for the incident 2007 Jeep Grand Cherokee [May 31, 2012]
- Alliance Claims Solutions – Estimate for the incident 2007 Jeep Grand Cherokee [June 19, 2012]
- Kadel's Cascade Auto Body – Supplement of Record 1 with Summary for the incident 2007 Jeep Grand Cherokee [June 18, 2012]
- Complaint, *Victoria N. Johnson v. Susan Ginther* [March 11, 2013]
- Defendant's Answer to Plaintiff's Complaint, *Victoria N. Johnson v. Susan Ginther* [April 12, 2013]
- Medical Records pertaining to Victoria Johnson
- VinLink data sheet for the subject 2006 Toyota Corolla
- Expert AutoStats data sheets for a 2006 Toyota Corolla
- Expert AutoStats data sheets for a 2003 Toyota Corolla

- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2003 Toyota Corolla
- VinLink data sheet for the incident 2005 Chrysler Pacifica
- Expert AutoStats data sheets for a 2005 Chrysler Pacifica
- VinLink data sheet for the incident 2007 Jeep Grand Cherokee
- Expert AutoStats data sheets for a 2007 Jeep Grand Cherokee

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanics that Ms. Johnson claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Johnson was occupying;
3. Determine Ms. Johnson's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Johnson's response to the subject incident;
5. Evaluate Ms. Johnson's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanics.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Johnson has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

ARCCA

- Thoracic, Lumbar and Sacral Spine
    - Sprain/strain
- Left Shoulder
    - SLAP tear
- Concussion

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject Toyota Corolla and incident Jeep Grand Cherokee in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Toyota and the Jeep, where the primary points of impact to the incident Jeep and the subject Toyota were to the front and rear, respectively.

The damage estimates of the subject Toyota Corolla indicated damage primarily to the rear bumper cover which required replacement and the rear bumper assembly required overhauling; this is consistent with the reviewed photographic reproductions (Figure 1). The damage estimates of the incident Jeep Grand Cherokee indicated frontal damage (from contact with the subject Toyota Corolla) primarily to the front bumper cover, front bumper bracket, front bumper license attachment package, front body lower crossmember, lower radiator support crossmember, right front body insulator, right stop bumper, and the front bumper assembly required overhauling; this is consistent with the reviewed photographic reproductions (Figure 2).

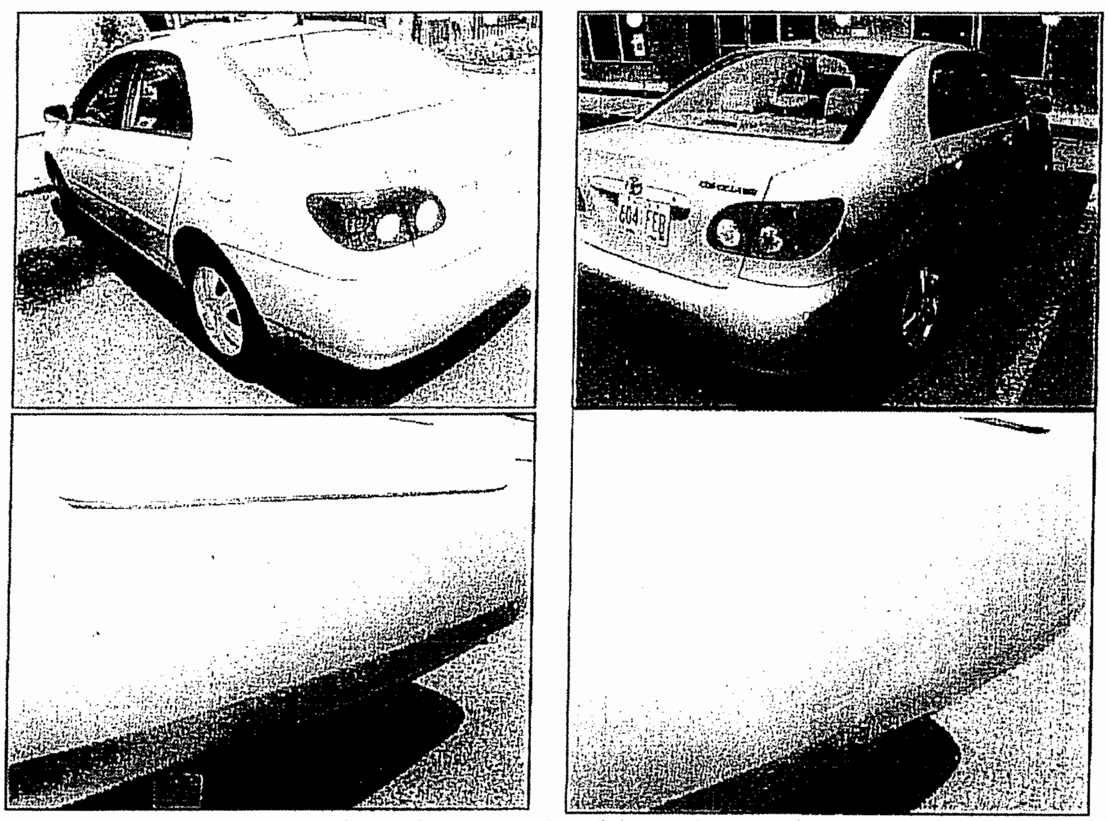

Figure 1: Reproductions of photographs of the subject 2006 Toyota Corolla

Figure 2: Reproductions of photographs of the incident 2007 Jeep Grand Cherokee

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Corolla, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The IIHS tested a 2003 Toyota Corolla, essentially the same vehicle as the subject 2006 Toyota Corolla, in a five mile-per-hour rear impact into a flat barrier. The test Toyota sustained damage to the rear bumper reinforcement which required replacement. The primary damage to the subject Toyota was to the rear bumper cover which required replacement and the rear bumper assembly required overhauling. Thus, because the test Toyota in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed comparable to the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 2006 Toyota Corolla and a 2007 Jeep Grand Cherokee.[12,13,14,15,16,17]

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11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Toyota Corolla. Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the peak acceleration associated with a 5 mile-per-hour impact is 2.3g.[18] By the laws of physics, the peak acceleration experienced by the subject Toyota in which Ms. Johnson was seated was comparable to 2.3g.

The acceleration experienced due to gravity is 1g. This means that Ms. Johnson experiences 1g of loading while in a sedentary state. Therefore, Ms. Johnson experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Johnson in her daily life would have increased the loading to her body beyond the sedentary 1g. According to the available documents, Ms. Johnson has a son and she was employed by Other-Affordable NW Exteriors. Additionally, Ms. Johnson drives and performs chores such as folding laundry, lifting a laundry basket, cooking, washing dishes, carrying groceries, and sweeping. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the peak acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Toyota in which Ms. Johnson was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Johnson's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According to the State of Washington Police Traffic Collision Report, Ms. Johnson was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Johnson's principle direction of motion would be rearward, relative to her vehicle. Additionally, the available documents indicate that Ms. Johnson was unaware of the impending impact, and she struck the seatbelt and headrest.

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15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

20 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

The laws of physics dictate that when the incident Jeep contacted the rear of the subject Toyota, had there been enough energy transferred to initiate motion, the Toyota would have been pushed forward, causing Ms. Johnson's seat to move forward relative to her body, which would result in Ms. Johnson moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Johnson and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Johnson would have been limited to well within the range of normal physiological limits.

Findings:

1. On May 15, 2012, Ms. Victoria Johnson was the belted driver of a 2006 Toyota Corolla that was contacted in the rear at low speed by a 2007 Jeep Grand Cherokee.
2. The change in velocity was comparable to 5 miles-per-hour with peak accelerations comparable to 2.3g.
3. The acceleration experienced by Ms. Johnson was within the limits of human tolerance, the personal tolerance levels of Ms. Johnson and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Johnson was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Johnson was diagnosed with a cervical sprain/strain.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota would be pushed forward and Ms. Johnson would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 Toyota Corolla, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 31.0 inches in the "full down" position and 33.5 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Johnson's age (34 years), height (67 inches) and weight (225 lbs), Ms. Johnson would have a normal seated height of 34.1 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Johnson and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Additionally, the medical records indicated that Ms. Johnson contacted the head restraint. With the minimal accelerations and the neck motions within a normal physiological range one would not expect traumatic biomechanical failures to the cervical spine.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Johnson in the subject incident. The subject incident had peak accelerations comparable to 2.3g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31] Ms. Johnson would not have been exposed to any loading or motion outside of her personal tolerance levels.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be a peak 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Johnson cannot be made.

Thoracic, Lumbar and Sacral Spine

The available documents indicate Ms. Johnson was diagnosed with a thoracic, lumbar and sacral sprain/strain.

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27 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

28 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic, lumbar, or sacral spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic, lumbar, or sacral spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had peak accelerations comparable to 2.3g. Ms. Johnson's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during

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34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

36 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar, and sacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Johnson, a causal link between the subject incident and claimed thoracic, lumbar and sacral biomechanical failures cannot be made.

Left Shoulder

An MR arthrogram of Ms. Johnson's left shoulder taken on November 9, 2012 indicated a mildly displaced labral tear and a tear through the posterior band of the inferior glenohumeral ligaments. Additionally, the medical records indicated Ms. Johnson had an SLAP tear in the left shoulder. SLAP (Superior Labrum Anterior-Posterior) is a term used to denote a specific type of biomechanical failure to the shoulder joint. The mechanism to create a SLAP biomechanical failure is if the arm is forcefully bent inward at the shoulder, the humerus acts as a lever and tears the biceps tendon and labrum cartilage from the glenoid cavity in a front-to-back (anterior-posterior) direction. The kinematics required for this motion would not be produced in the subject incident.

There is no reason to assume that the claimed bilateral shoulder biomechanical failure is causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Toyota Corolla would be pushed forward and Ms. Johnson would have moved rearward relative to the vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of Ms. Johnson's shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Johnson's body away from the seatback.[44] The available documents indicated Ms. Johnson was wearing the available three-point restraint, therefore any load acting on the shoulder area due to restraint forces would have been dispersed over Ms. Johnson's left shoulder, torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause acute shoulder trauma to her shoulders. The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Johnson's shoulders would have been limited to well within the range of normal physiological limits.

Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The two mechanisms for rotator cuff biomechanical failure are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the shoulder joint.[45] The supraspinatus tendon is commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming. These mechanisms were not created in the subject collision.

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43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

44 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

45 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins

Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

The subject incident had a peak acceleration level that was comparable to 2.3g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder biomechanical failures were reported. [46,47,48,49,50] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[51,52,53,54] As a result, Ms. Johnson's shoulders would not have been exposed to any loading forces outside the her personal tolerance range.

The subject incident lacks the appropriate biomechanical failure mechanism to produce acute trauma to the left shoulder. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Ms. Johnson would tend to move rearward relative to the subject vehicle. For these reasons, a causal link between the subject incident and the shoulder biomechanical failures claimed by Ms. Johnson cannot be made.

Concussion

The available documents indicate Ms. Johnson was diagnosed with a concussion.

A brain biomechanical failure without skull fracture is classified as a mild diffuse brain biomechanical failure or concussion.[55,56] Acute onset of concussion requires that the brain tissue be stretched and/or strained beyond physiological limits.[57,58,59,60] The biomechanical failure mechanism required to cause a concussion is loading to the brain that causes stretching and/or straining of the brain tissue beyond

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46 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

48 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

49 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). Rear-end Impact Testing with Human Test Subjects (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

50 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

51 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living," Journal of Biomechanics, In Press.

52 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

53 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

54 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

55 Gennarelli, T.A., (1982) "Impact Injury Caused by Linear Acceleration: Mechanisms, Prevention, and Cost." NATO AGARD Conference 1-9.

56 Viano, D.C. Biomechanics of Head Injury – Toward a Theory Linking Head Dynamic Motion, Brain Tissue Deformation and Neural Trauma, (SAE 881708). Warrendale, PA. Society of Automotive Engineers.

57 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

58 Gennarelli, T.A., (2003) "Mechanisms of Brain Injury." Journal of Emergency Medicine 11: 5-11.

59 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma*, 66(2):309-315.

60 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma*, 12(4):621-625.

physiological limits. These biomechanical failures are associated with substantial impulsive or impact loads applied to the head.[61]

The subject incident lacked the energy necessary to cause Ms. Johnson's diagnosed concussion.[62,63] As described previously, had the loads associated with the subject incident been sufficient to overcome Ms. Johnson's muscle reaction forces, her body would have moved rearward relative to the Toyota's interior. The seatback structure and three-point restraint that Ms. Johnson was wearing would have limited her body motion. During this response, Ms. Johnson's head would have been subjected to some degree of rearward extension upon impact, and potential head contact with the headrest. However, this potential head contact would not have generated enough energy to cause biomechanical failure or trauma to the head. [64]

The Head Injury Criterion (HIC) has been adopted by the United States federal government as the standard criterion for the determination of risk of a head biomechanical failure for the Federal Motor Vehicle Safety Standards (FMVSS). In brief, HIC is calculated from resultant accelerations at the center of gravity of the head (based upon three orthogonal directions) that are optimized over a duration of impact. FMVSS 201, titled Occupant Protection in Interior Impact, specifies requirements to afford impact protection for occupants.[65] More specifically, FMVSS 201 is related to the likelihood of biomechanical failure resulting from occupant head contact with the interior of a vehicle. FMVSS 201 dictates that when the interior of a vehicle is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, HIC(d), an acronym for Head Injury Criterion (dummy), should not exceed 1000 for any two points in time during the impact which are separated by not more than a 36 millisecond time interval. FMVSS 201 further dictates that when a seatback is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, the deceleration of the headform shall not exceed 80g continuously for more than 3 milliseconds. This requirement is consistent with previous research published by Ono et al. that investigated the human head impact tolerance and the threshold for concussion.[66]

FMVSS 202a, titled Head Restraints, specifies new requirements for head restraints to reduce the frequency and severity of head and neck biomechanical failures in rear-end and other collisions.[67] More specifically, FMVSS 202a specifies that during dynamic rear impact testing at accelerations of approximately 9.4g, HIC should not exceed 500 for any two points in time during the impact which are separated by not more than a 15-millisecond time interval.

This subject incident had peak accelerations comparable to 2.3g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[68,69] accelerations of the head and spinal

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61 Goldsmith, W., (2001) "The State of Head Injury Biomechanics: Past, Present, and Future: Part 1." Critical Reviews in Biomedical Engineering 29 (5 & 6): 441-600.

62 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma*, 66(2):309-315.

63 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma*, 12(4):621-625.

64 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

65 Federal Motor Vehicle Safety Standard 571.201. Occupant Protection in Interior Impact.

66 Ono, K., Kikuchi, A., et al. (1980). Human Head Tolerance to Sagittal Impact Reliable Estimation Deduced from Experimental Head Injury Using Subhuman Primates and Human Cadaver Skulls. (SAE 801303). Warrendale, PA, Society of Automotive Engineers.

67 Federal Motor Vehicle Safety Standard 571.202a. Head Restraints.

68 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities". Biomed Sci Instrum, 42:410-415.

structures were measured during activities of daily living. Peak accelerations of the head were measured to be a peak 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature, the subject incident created accelerations that were well within human tolerance and were comparable to accelerations applied during daily activities. Therefore, the subject incident was within Ms. Johnson's personal tolerance. In addition, the loads associated with the subject incident were not applied in the proper manner or with sufficient magnitude to generate the biomechanical failure mechanism necessary for her diagnosed brain biomechanical failure. As this crash event did not apply loads of sufficient magnitude to exceed Ms. Johnson's personal tolerance and the necessary biomechanical failure mechanism was not created, causation between the subject incident and her diagnosed concussion cannot be established.

Personal Tolerance Values

As noted previously, Ms. Johnson has a son and she was employed by Other-Affordable NW Exteriors. Additionally, Ms. Johnson drives and performs chores such as folding laundry, lifting a laundry basket, cooking, washing dishes, carrying groceries, and sweeping. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Johnson and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[70]

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 15, 2012, Ms. Victoria Johnson was the belted driver of a 2006 Toyota Corolla that was contacted in the rear at low speed by a 2007 Jeep Grand Cherokee.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with peak acceleration comparable to 2.3g for the subject 2006 Toyota Corolla in which Ms. Johnson was seated.
3. The acceleration experienced by Ms. Johnson was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Johnson's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

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69 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

70 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

ARCCA

6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed thoracic, lumbar and sacral spine biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar, and sacral biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Johnson's claimed concussion. As such, a causal relationship between the subject incident and concussion cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
Probst 32
5-23-17

June 25, 2013

Christopher Nye, Esquire
Reed McClure
1215 Fourth Avenue
Suite 1700
Seattle, WA 98161

Re: *Wolf, Laura v. Melissa Stevens*
ARCCA Case No.: 4376-002

Dear Mr. Nye:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanics involved in the incident of Laura Wolf. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanics.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical effect.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

Incident Description:

A police incident report was not available for the subject incident, thus the following incident description is based upon the available documents. On June 15, 2009, Ms. Laura Wolf was the restrained driver of a 2000 Subaru Outback traveling eastbound on John Street near the intersection of 13th Avenue in Seattle, Washington. Ms. Melissa Stevens was the driver of a Hyundai Elantra that was traveling directly behind the Subaru. According to the available documents, the Subaru was stopped waiting for a vehicle in front to turn left, and was struck from behind by the incident Hyundai. As a result, the front of the incident Hyundai contacted the rear of the subject Subaru. No airbags were deployed in the subject Subaru as a result of the impact, and the subject Subaru was capable of driving from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Vehicle Collision Report
- Seventeen (17) color photographic reproductions of the subject 2000 Subaru Outback
- Nine (9) grayscale photographic reproductions of the subject 2000 Subaru Outback
- Two (2) color photographic reproductions of the incident Hyundai
- Country Financial – Estimate for the subject 2000 Subaru Outback [June 24, 2009]
- Havlick's Auto Rebuild – Invoice for the subject 2000 Subaru Outback [September 11, 2009]
- Havlick's Auto Rebuild – Preliminary Estimate for the subject 2000 Subaru Outback [August 19, 2009]
- American Family Insurance – Estimate for the subject 2000 Subaru Outback [August 11, 2009]
- Havlick's Auto Rebuild – Estimate for the subject 2000 Subaru Outback [August 19, 2009]
- Havlick's Auto Rebuild – Supplement 1 for the subject 2000 Subaru Outback [August 26, 2009]
- Complaint, *Laura D. Wolf v. Melissa Stevens and John Doe Stevens* [March 29, 2012]
- Deposition Transcript of Laura Wolf [April 26, 2013]
- Plaintiff's First Interrogatories to Defendant and Answers Thereto, *Laura D. Wolf vs. Melissa Stevens and John Doe Stevens* [January 18, 2013]
- Pattern Interrogatories to Plaintiff Laura D. Wolf, *Laura D. Wolf vs. Melissa Stevens and John Doe Stevens* [December 10, 2012]
- Requests for Production of Documents to Plaintiff Laura D. Wolf, *Laura D. Wolf vs. Melissa Stevens and John Doe Stevens* [December 10, 2012]
- Recorded Statement Transcript of Laura Wolf [August 10, 2009]
- Medical Records pertaining to Laura Wolf
- VinLink data sheet for the subject 2000 Subaru Outback
- Expert AutoStats data sheets for a 2000 Subaru Outback
- Expert AutoStats data sheets for a 2000 Subaru Legacy
- Insurance Institute for Highway Safety Low-Speed Crash Test Report for a 2000 Subaru Legacy
- Expert AutoStats data sheets for a 2001 Hyundai Elantra

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Wolf claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Wolf was occupying;
3. Determine Ms. Wolf's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Wolf's response to the subject incident;
5. Evaluate Ms. Wolf's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanics.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Wolf has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
- Right Shoulder
  - Rotator cuff tear

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject Subaru Outback and incident Hyundai Elantra and the available repair estimates of the subject Subaru Outback in association with accepted scientific methodologies. According to the available documents, the subject incident was a rear impact between the Subaru and the Hyundai, where the primary points of impact to the incident Hyundai and the subject Subaru were to the front and rear, respectively.

The damage estimate of the subject Subaru Outback indicated damage primarily to the rear bumper cover, trailer hitch, left and right muffler hanger, and the rear bumper required an overhaul; this is consistent with the reviewed photographic reproductions (Figure 1) According to Ms. Wolf's testimony, the hitch had taken the impact. The photographs of the incident Hyundai Elantra indicated damage to the center of the front bumper (Figure 2).

Figure 1: Reproductions of photographs of the subject 2000 Subaru Outback

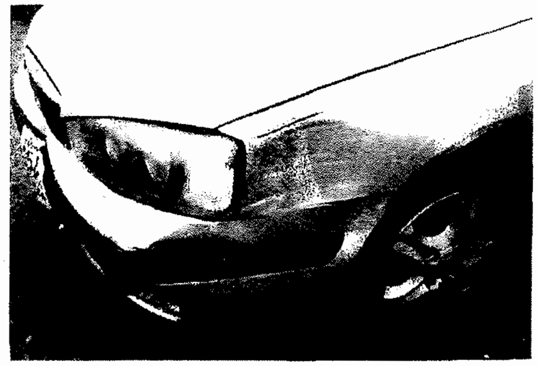

Figure 2: Reproductions of photographs of the incident Hyundai Elantra

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested an exemplar 2000 Subaru Legacy in a 5 mile-per-hour rear center impact into a rigid pole. As previously noted in Ms. Wolf's testimony, the hitch was pushed into the rear bumper of the subject Subaru upon impact, thus the damage to the subject Subaru from the subject incident impact is comparable to striking a rigid pole. The damage to the subject Subaru Outback, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11] The test Subaru sustained damage to the rear bumper reinforcement and left and right rear bumper mounting plate. The primary damage to the subject Subaru was to the rear bumper cover, trailer hitch, left and right muffler hanger, and the rear bumper required an overhaul. Thus, because the test Subaru in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed comparable to the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an energy-based crash analysis of a 2000 Subaru Outback.[12,13,14,15,16,17]

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V comparable to 5 miles-per-hour for the subject Subaru Outback. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour impact is 1.5g.[18] By the laws of physics, the peak acceleration experienced by the subject Subaru in which Ms. Wolf was seated was comparable to 1.5g.

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11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

16 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA, Society of Automotive Engineers.

The acceleration experienced due to gravity is 1g. This means that Ms. Wolf experiences 1g of loading while in a sedentary state. Therefore, Ms. Wolf experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Wolf in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Wolf testified that she was employed at the time of the subject incident as an Executive Assistant for Seattle Times where she supported the Senior Vice President of sales and marketing. Additionally, Ms. Wolf testified that she participated in skiing for her whole life, went running two to three times a week, and she participated on a dodge ball team regularly before the subject incident. Ms. Wolf further went kayaking twice each year and white water rafting once a year before the subject incident. Ms. Wolf was a member at a gym, Rain Fitness, and participated in weight training, organized aerobics and yoga classes, and used the cardio machine. Furthermore, Ms. Wolf testified that she went skiing, kayaking, bouldering at a climbing gym, and performed pushups after the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the peak acceleration associated with the subject incident.[20]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Subaru in which Ms. Wolf was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Wolf's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

According to her testimony, Ms. Wolf was wearing the available three-point restraint system at the time of the subject incident. Had any of the forces been great enough to overcome muscle reactions, Ms. Wolf's principle direction of motion would be rearward, relative to her vehicle. Additionally, Ms. Wolf testified she was unaware of the impending impact and had her hands on the steering wheel. Furthermore, Ms. Wolf testified she hit the back of her head on the headrest.

The laws of physics dictate that when the incident Hyundai contacted the rear of the subject Subaru, had there been enough energy transferred to initiate motion, the Subaru would have been pushed forward, causing Ms. Wolf's seat to move forward relative to her body, which would result in Ms. Wolf moving rearward relative to the interior of the subject vehicle. This interaction between Ms. Wolf and the subject vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat

[19] Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

[20] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

back.[21,22,23] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Wolf would have been limited to well within the range of normal physiological limits.

Findings:

1. On June 15, 2009, Ms. Laura Wolf was the belted driver of a 2000 Subaru Outback that was contacted in the rear at low speed by a Hyundai Elantra.
2. The change in velocity was comparable to 5 miles-per-hour with average accelerations comparable to 1.5g.
3. The acceleration experienced by Ms. Wolf was within the limits of human tolerance, the personal tolerance levels of Ms. Wolf and comparable to that experienced during various daily activities.

Evaluation of Biomechanical failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Wolf was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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21 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

22 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

23 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

24 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

25 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Cervical Spine

According to the available documents, Ms. Wolf was diagnosed with a cervical sprain/strain.

In a rear impact that produces motion of the subject vehicle, the Subaru would be pushed forward and Ms. Wolf would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2000 Subaru Outback, showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 30.5 inches in the "full down" position and 33.0 inches in the "full up" position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Wolf's age (29 years), height (69 inches) and weight (170 lbs), Ms. Wolf would have a normal seated height of 34.8 inches. Thus the seat is tall enough to have prevented hyperextension of Ms. Wolf and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Additionally, Ms. Wolf testified that her head struck the headrest upon impact.

West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[26] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. In testing that simulated an automobile collision environment, Mertz and Patrick subjected a volunteer to multiple rear-end impacts, both with and without a head restraint.[27] The authors subjected the volunteer to rear-end collisions with peak accelerations of 17g in the presence of a head restraint and 6g in the absence of a head restraint, without the production or onset of severe cervical biomechanical failure. In a study documented in the European Spine Journal, male volunteers and female volunteers participated in 17 rear-end type vehicle collisions with a range of mean accelerations between 2.1g and 3.6g, and 3 bumper car collisions with a range of mean accelerations between 1.8g and 2.6g, without sustaining any severe cervical biomechanical failures.[28] Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical

[26] West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[27] Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

[28] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K., (1997) "Do "whiplash injuries" occur in low-speed rear impacts?" *European Spine Journal*, 6:366-375.

failure threshold is 5g.[29] The above research describes the response of human volunteers subjected to rear-end impacts of comparable or greater severity to that experienced by Ms. Wolf in the subject incident. The subject incident had an average acceleration comparable to 1.5g. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30,31]

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[32,33] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Thoracic and Lumbar Spine

The available documents indicate Ms. Wolf was diagnosed with a thoracic and lumbar sprain/strain.

As previously described, in a rear impact of the type seen here, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents injurious motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. Neither the mechanism nor the force magnitude associated with thoracic, and lumbar spine damage are created by this event. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine.

As previously described, West et al. subjected five volunteers, aged 25 to 43 years, to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[34] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Szabo et al. subjected male and female volunteers, aged 27 to 58 years, with various degrees of cervical and lumbar spinal degeneration to rear-end impacts with the Delta-V of the struck vehicle approximately 5 mph.[35] The impacts caused no biomechanical failure to any of the volunteers, and no objective change in the conditions of their lumbar spines. Previous research focusing on physiological

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29 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

30 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

31 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

32 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

33 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

34 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

35 Szabo, T.J., Welcher, J.B., et al., (1994) Human Occupant Kinematic Response to Low Speed Rear-End Impacts, (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

responses to impact and the dynamic relationship between response parameters and biomechanical failure has exposed live human subjects' torsos to rear g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[36] The subject incident had an average acceleration comparable to 1.5g. Ms. Wolf's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[37,38,39,40,41] Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[43]

Shoulders

According to medical records, Ms. Wolf had a rotator cuff tear in the right shoulder. An MRI report of the right shoulder dated May 18, 2011, indicated extensive tendinosis with partial tearing of the tendon thickness from the bursal surface involving the supraspinatus extends from the subacromial space to the foot print, tendinosis of the subscapularis lateral articular segment, and mild subdeltoid bursitis. Additionally, an operation report for Ms. Wolf's right shoulder dated May 31, 2011, indicated a right shoulder rotator cuff repair and subacromial decompression.

Tendinitis is an inflammation of the tendon and/or its sheath and is associated with a repetitive strain biomechanical failure and not associated with acute trauma.[44,45,46] Tendinitis is also known as tendinosis. Tendinosis is an intratendinous breakdown of collagen due to aging, microtrauma or vascular compromise[47]. It is often seen in athletes (pitchers in baseball) and laborers (painters) who work with their arms above their heads (shoulders abducted). Overuse is commonly cited as a primary risk for tendinosis and tenosynovitis.

There is no reason to assume that the claimed right shoulder biomechanical failure is causally related to the subject incident. As described previously, in a rear impact that produces motion of the vehicle, the subject Subaru would be pushed forward and Ms. Wolf would have moved rearward relative to the

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36 Weiss M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

38 Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

39 Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

40 Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

41 Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

42 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

43 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

44 Almekinders, L.C., Banes, A.J., Ballenger, C.A.," *Effects of Repetitive Motion on Human Fibroblasts*," Med Sci Sports Exerc 1993 May 25:603-7

45 O'Neil, B.A., Forsythe, M.E., Stanish, W.D., "*Chronic Occupational Repetitive Strain Injury*," Can Fam Physician 2001 Feb 47:311-6

46 Nakano, K.K., "*Peripheral Nerve Entrapments, Repetitive Strain Disorder, Occupation-Related Syndromes, Bursitis And Tendonitis*," Curr Opin Rheumatol 1991 Apr 3:226-39

47 Khan KM, Cook JL, Taunton JE, and Bonar F, "Overuse Tendinosis, Not Tendinitis, *The Physician and Sportsmedicine*, Vol 28, No 5, May 2000.

vehicle, until her motion was halted by the seatback. This interaction with the seatback would both limit the motion of Ms. Wolf's shoulders and minimize any forces that might be applied. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Ms. Wolf's body away from the seatback.[48] The available documents indicated Ms. Wolf was wearing the available three-point restraint, therefore any load acting on the shoulder area due to restraint forces would have been dispersed over Ms. Wolf's left shoulder, torso and pelvis, thereby minimizing any shoulder loads. As a result, the subject incident did not create any of the biomechanical failure mechanisms necessary to cause acute shoulder trauma to her shoulders. The low accelerations in the subject incident and the restraint provided by the seatback, then, were such that any motion of Ms. Wolf's shoulders would have been limited to well within the range of normal physiological limits.

Injuries to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The two mechanisms for rotator cuff biomechanical failure are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the shoulder joint.[49] The supraspinatus tendon is commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming. These mechanisms were not created in the subject collision. Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

The subject incident had an average acceleration level that was comparable to 1.5g. This acceleration level is within human tolerance limits and comparable to, or below that applied to human volunteers subjected to rear-end impacts in which no shoulder injuries were reported. [50,51,52,53,54] Previous research has shown that shoulder loads during activities of daily living such as manipulating a coffee pot, or relatively benign reaching and lifting tasks generate shoulder loads that are comparable to, or greater than that associated with the subject incident.[55,56,57,58] A study by Lucas et al has also shown that rear-end impacts with a Delta-V of up to 12.2 miles per hour do not produce the required force to injure the

48 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

49 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins

50 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

51 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

52 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

53 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). Rear-end Impact Testing with Human Test Subjects (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

54 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

55 Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

56 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

57 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

58 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

ligaments of the shoulder.[59] As previously noted, Ms. Wolf testified that she participated in skiing, kayaking, weight training, and performed pushups. As a result, Ms. Wolf's shoulders would not have been exposed to any loading forces outside the her personal tolerance range in the subject incident. The subject incident lacks the appropriate biomechanical failure mechanism to produce acute trauma to the right shoulder. The loading and kinematics of these body parts were well within the limits of human tolerance and physiological motion. Ms. Wolf would tend to move rearward relative to the subject vehicle. For these reasons, a causal link between the subject incident and the shoulder biomechanical failures claimed by Ms. Wolf cannot be made.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Wolf's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Wolf using peer-reviewed and generally-accepted methodologies.

Personal Tolerance Values

As noted previously, Ms. Wolf testified that she was employed at the time of the subject incident as an Executive Assistant for Seattle Times where she supported the Senior Vice President of sales and marketing. Additionally, Ms. Wolf testified that she participated in skiing for her whole life, went running two to three times a week and she participated on a dodge ball team regularly before the subject incident. Ms. Wolf further went kayaking twice each year and white water rafting once a year before the subject incident. Ms. Wolf was a member at a gym, Rain Fitness, and participated in weight training, organized aerobics and yoga classes and used the cardio machine. Furthermore, Ms. Wolf testified that she went skiing, kayaking, bouldering at a climbing gym, and performed pushups after the subject incident. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Wolf and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[60]

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On June 15, 2009, Ms. Laura Wolf was the belted driver of a 2000 Subaru Outback that was contacted in the rear at low speed by a Hyundai Elantra.
2. The severity of the subject incident was consistent with a Delta-V comparable to 5 miles-per-hour with an average acceleration comparable to 1.5g for the subject 2000 Subaru Outback in which Ms. Wolf was seated.

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59 Lucas, S., et al (2009) Analysis of Shoulder Ligament Injury Potential in Automotive Rear-End Impacts (SAE 2009-01-1203). Warrendale, PA. Society of Automotive Engineers.

60 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

ARCCA

3. The acceleration experienced by Ms. Wolf was within the limits of human tolerance and comparable to that experienced during various daily activities.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Wolf's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

There is no biomechanical failure mechanism present in the subject incident to account for Ms. Wolf's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document. My opinions are provided on a more probable than not basis.

I declare, under the penalties of perjury, that the information contained within my report was prepared by and is the work of the undersigned, and is true and correct to the best of my knowledge and information.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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February 21, 2014

Adrienne Harris, Esquire
Law Offices of Kenneth R. Scearce
1501 4th Avenue
Suite 420
Seattle, WA 98101

Re: *Price, Catherine v. Gordon Luna*
Claim No.: HEN2267 (WFS)
ARCCA Case No.: 2240-222

Dear Ms. Harris:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Catherine Price. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.
2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.
3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.
4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.
5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The Complaint and other available documents reported that on March 4, 2011, Ms. Robin Price was the driver of a 2006 Ford F350 traveling near 731 3rd Street S in Kirkland, Washington. Ms. Catherine Price was the seat belted right front passenger of the 2006 Ford F350. Mr. Gordon Luna was the driver of a 1999 Dodge Grand Caravan backing out of his driveway at 731 3rd Street S in Kirkland, Washington. According to the available documents, the subject Ford F350 was slowly traveling along the roadway and the incident Dodge Grand Caravan continued to back up. As a result, the right rear corner of the incident Dodge contacted the right rear side of the subject Ford. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Ten (10) color photographic reproductions of the subject 2006 Ford F350
- Twenty-three (23) color photographic reproductions of the incident 1999 Dodge Grand Caravan
- Travelers repair estimate for the subject 2006 Ford F350 [March 7, 2011]
- Travelers Supplement of Record 1 with Summary for the subject 2006 Ford F350 [March 31, 2011]
- Juanita Collision Center, LLC. Preliminary Supplement 1 with Summary [March 30, 2011]
- Travelers repair estimate for the incident 1999 Dodge Grand Caravan [March 7, 2011]
- Travelers Supplement of Record 1 with Summary for the incident 1999 Dodge Grand Caravan [March 10, 2011]
- Travelers Supplement of Record 2 with Summary for the incident 1999 Dodge Grand Caravan [April 4, 2011]
- Complaint for Personal Injuries, *Catherine Ann Price v. Gordon Luna and "Jane Doe" Luna* [May 16, 2013]
- Defendants' First Interrogatories and Requests for Production of Documents Directed to Plaintiff and Plaintiff's Answers and Responses Thereto, *Catherine Ann Price v. Gordon Luna and "Jane Doe" Luna* [July 22, 2013]
- Plaintiff's First Set of Interrogatories and Requests for Production Propounded to Defendant, Gordon Luna and Responses Thereto, *Catherine Ann Price v. Gordon Luna and "Jane Doe" Luna* [July 29, 2013]
- Recorded Statement Transcript of Robin Price [March 4, 2011]
- Medical Records pertaining to Catherine Price
- VinLink data sheet for the subject 2006 Ford F350
- Expert AutoStats data sheets for a 2006 Ford F350
- VinLink data sheet for the incident 1999 Dodge Grand Caravan
- Expert AutoStats data sheets for a 1999 Dodge Grand Caravan

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Price claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle;
3. Determine Ms. Price's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Price's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Price has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Multilevel disc bulges, osteophytes and protrusions
- Left and Right Thoracic Outlet Syndrome

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographs and repair estimates of the subject Ford F350 and incident Dodge Grand Caravan in association with accepted scientific methodologies.

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[6] Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

[7] Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

[10] Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

The damage estimate of the subject Ford F350 indicated damage primarily to the rear bumper, right rear bumper step pad, right tail lamp assembly, right tail lamp cover, right side bed panel, bed rear sill, right rear pillar, and required a pull to the right side bed with rear sill, which is consistent with the available photographs (Figure 1). According to Ms. Price's statement, there was denting and scraping to the right rear side and bumper on the subject Ford.

Figure 1: Photographs of the subject 2006 Ford F350

The damage estimate of the incident Dodge Grand Caravan indicated damage primarily to the right combination lamp, lift gate, right tail lamp opening extension, pull right quarter, right trough rear drain, and right side moulding, which is consistent with the available photographs (Figure 2). According to Ms. Price's statement, there was damage to the right rear tail light on the incident Dodge. Further, the Plaintiff's First Set of Interrogatories and Requests for Production Propounded to Defendant, Gordon Luna and Responses Thereto, indicated there was damage to the right rear tail light and lift gate on the incident Dodge.

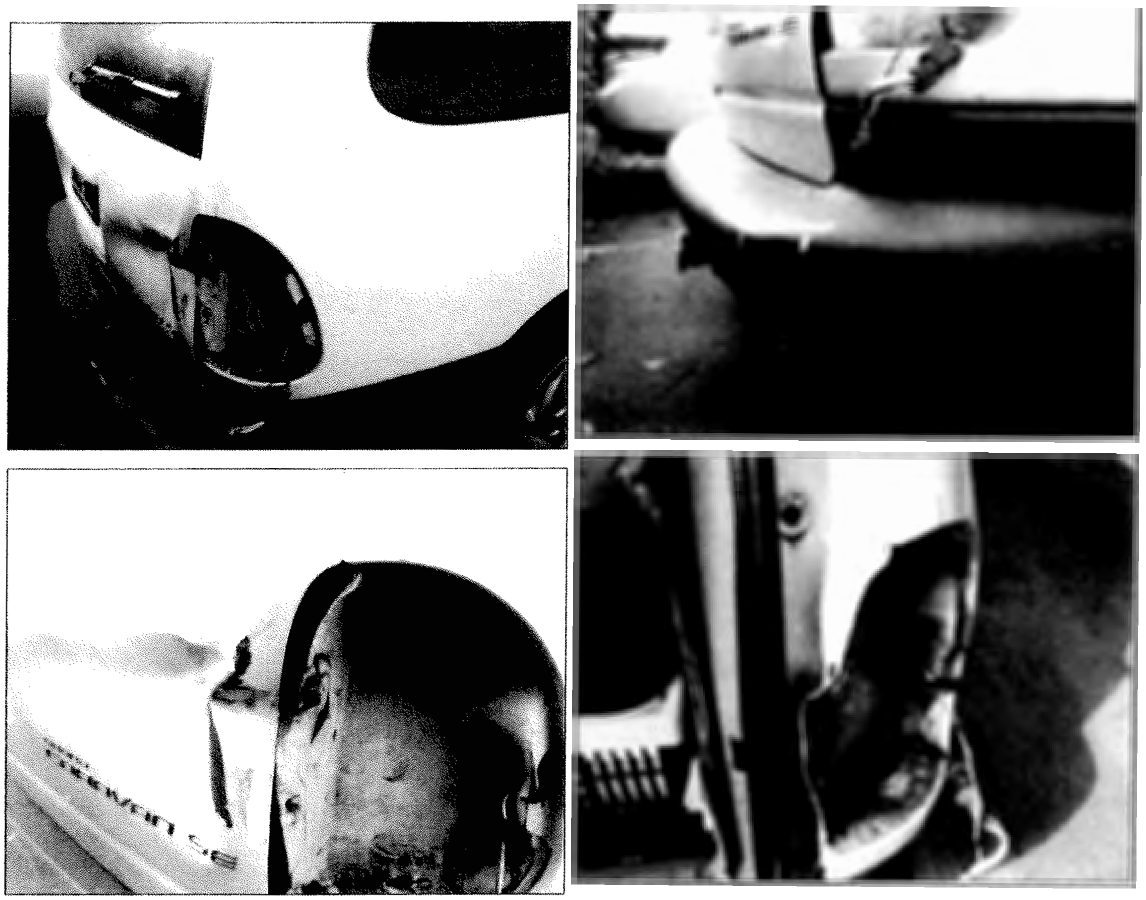

Figure 2: Photographs of the incident 1999 Dodge Grand Caravan

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Dodge Grand Caravan can be used to resolve the loads sustained by the subject Ford F350. That is, the loads sustained by the incident Dodge Grand Caravan are equal and opposite to those of the subject Ford F350.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographic reproductions, and confirmed by the repair record, of the incident Dodge Grand Caravan and geometric measurements of a 1999 Dodge Grand Caravan revealed the damage due to the subject incident. An energy crush analysis[16] indicates that a single 10 mile-per-hour flat barrier impact to the right rear corner of a Dodge Grand Caravan would result in significant and visibly noticeable crush across the right rear corner of the incident vehicle's structure, with a residual crush of 6.75 inches over a width of 19 inches.

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile-per-hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity to its post-impact velocity) impact than that of the subject incident.[17] The lack of significant structural crush to the right rear corner of the incident Dodge Grand Caravan indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 5.9 miles per hour for the subject Ford F350.

The forces, velocities, and accelerations experienced during the incident by the subject Ford F350 were evaluated using the results of the above energy-based crush analysis along with the conservation of linear momentum.[18,19,20] Review of the vehicle damage, incident data, published literature, scientific analyses, the conservation of momentum, and my experience indicates an incident resulting in a Delta-V significantly below 5.9 miles per hour for the subject Ford F350. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5.9 mile-per-hour impact is 1.8g.[21] By the laws of physics, the average acceleration experienced by the subject Ford F350 in which Ms. Price was seated was less than 1.8g.

The available documents indicate Ms. Price actively worked at various jobs around the time of the subject incident. Additionally, the documents indicate she participated in exercising, bicycling, yoga, horseback riding, running, and hiking, among other activities. Ms. Price's medical records also indicate she participated in yoga and exercise. The acceleration experienced due to gravity is 1g. This means that Ms. Price experiences 1g of loading while in a sedentary state. Therefore, Ms. Price experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Price in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events such as slowly climbing stairs, standing on one leg, or rising from a chair are capable of such forces.[22] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance; the energy imparted to the Ford F350 in which Ms. Price was the seat belted right front passenger was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Price's claimed biomechanical failures in the subject incident.

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17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View. (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

19 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA. Society of Automotive Engineers.

20 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems (SAE 2003-01-0492). Warrendale, PA. Society of Automotive Engineers.

21 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration. (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

22 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

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Kinematic Analysis:

According to the available documents, Ms. Price was wearing the available three-point restraint system at the time of the subject incident. Ms. Price's medical records indicate she was unaware of the impending collision. Further, the medical records reported she was slightly turned left and struck the passenger's side door upon impact. The Defendants' First Interrogatories and Requests for Production of Documents Directed to Plaintiff and Plaintiff's Answers and Responses Thereto, specifically indicates Ms. Price's right forearm struck the passenger's side door.

The laws of physics dictate that when the incident Dodge Grand Caravan contacted the right rear side of the subject Ford F350, had there been enough energy transferred to initiate motion, the Ford would have been accelerated laterally toward the left. Upon impact, had the forces generated during this interaction been sufficient to overcome the muscle reaction forces of Ms. Price, her body would have moved rightward relative to the Ford's interior. The three-point restraint that Ms. Price was wearing would have supported and limited body excursion. Support from the passenger's side door interior and friction generated at the seat bottom of Ms. Price, as well as the passive muscle resistance of her arms, would have acted in conjunction with her three-point restraint to limit body motion. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Price would have been limited to well within the range of normal physiological limits.

Findings:

1. On March 4, 2011, Ms. Catherine Price was the seat belted right front passenger of a 2006 Ford F350 traveling slowly near 731 3rd Street S in Kirkland, Washington that was contacted in the right rear side at low speed by a 1999 Dodge Grand Caravan.
2. The change in velocity was less than 5.9 miles per hour with an average acceleration less than 1.8g.
3. The acceleration experienced by Ms. Price was within the limits of human tolerance, the personal tolerance levels of Ms. Price, and comparable to that experienced during various daily activities.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Price was well within the limits of human tolerance and well below the acceleration levels that they experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[23,24]

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[23] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[24] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the available documents, Ms. Price attributes a cervical sprain/strain along with multilevel intervertebral disc bulges, osteophytes, and protrusions to the subject incident.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. The subject incident resulted in a side impact with an incident Dodge Grand Caravan. Had the forces generated been sufficient to overcome Ms. Price's muscle reaction forces, her body would have moved rightward relative to the Ford's interior. This motion would have been supported and constrained by the three-point restraint, passenger's side door interior, and seat bottom friction of the subject Ford F350. Ms. Price's cervical spine would have been subjected to a controlled degree of lateral bending during the subject incident. That is, head flexion is anatomically limited in lateral bending by head-to-shoulder contact.[25] As a result, Ms. Price's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[26] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[27,28]

Zaborowski and Ewing have conducted several investigations that exposed human volunteers to lateral impact accelerations.[29,30,31,32] In response to these tests, physical complaints were transient in nature

25 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

26 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

27 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

28 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

29 Zaborowski, A.B., (1964) Human Tolerance to Lateral Impact with Lap Belt Only. (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

30 Zaborowski, A.B., (1964) Lateral Impact Studies: Lap Belt Shoulder Harness Investigations. (SAE 650955). Warrendale, PA. Society of Automotive Engineers.

31 Ewing, C., Thomas, D., et al., (1977) Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration. (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

32 Ewing, C., Thomas, D., et al., (1978) Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration. (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

and none of the participants sustained or reported any cervical spine injuries. Fugger et al.[33] conducted lower severity lateral impacts with human volunteers. Physical complaints following these tests were noted following five tests, but complaints were transient in nature and consisted of back pain or slight headache that lasted a few minutes. Lateral impact research by Bailey et al.[34] again demonstrated that human volunteers sustained comparable severity lateral impacts without the onset of cervical spine injuries. These data are consistent with safe human exposure guidelines to lateral impact accelerations.[35,36]

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[37,38] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al. [39,40] demonstrated that a simple head shake, plopping into a chair, or a self-inflicted hand strike to the head induce accelerations comparable to or greater than the subject incident. These studies demonstrate that cervical compressive forces and accelerations during activities are comparable to or greater than those during the subject incident.[41] The available documents indicate Ms. Price participated in activities such as hiking, horseback riding, bicycling, tennis, and golf which would subject her to comparable or greater loading than the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Price cannot be made.

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33 Fugger, T.F., et al., (2002) Human Occupant Kinematics in Low Speed Side Impacts, (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

34 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

35 Eiband, A.M., (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

36 Weiss, M.S., Lustick, L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

38 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

39 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

40 Funk, J.R., Cormier, J.M., et al., (2011) "Head and Neck Loading in Everyday and Vigorous Activities." *Annals of Biomedical Engineering*, 39(2):766-776.

41 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

Thoracic Outlet Syndrome

According to the available documents, Ms. Price attributes bilateral thoracic outlet syndrome to the subject incident.

The neurogenic variety of thoracic outlet syndrome (TOS) is produced by compression of the components of the brachial plexus, which is a braid of nerves that pass from the neck to the arm. The thoracic outlet is the space between the collarbone and the first rib. Acute TOS is a complication of a cervical sprain/strain that causes scalene muscle spasm and scalene triangle narrowing.[42] The mechanism for thoracic outlet syndrome is an action that results in narrowing of the outlet, such as abducting the arm to 180 degrees (e.g. falling) or a vertically directed force that forces the shoulders down and back. However, in the subject incident the load path is in a horizontal orientation. Therefore, a biomechanical failure mechanism for the claimed thoracic outlet syndrome does not exist. Additionally, thoracic outlet syndrome is caused by several activities, such as poor posture and/or repetitive activities with outstretched or over head arm use such as working on computers.[43] The available documents indicate Ms. Price worked retail jobs as a sales associate and jobs that involved desk work such as a receptionist and book keeper. During the subject incident, Ms. Price's head would have moved rightward with minimal motion in the thoracic region, and her cervical spine motion would have been maintained to within normal physiological limits during the subject incident. Additionally, any right arm contact with the passenger's side door would direct Ms. Price's arm upward and toward the body, which is not the necessary direction to provide a biomechanical failure mechanism.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the upper torso. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic outlet region and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Price, a causal link between the subject incident and claimed bilateral thoracic outlet syndrome cannot be made.

Personal Tolerance Values:

As noted previously, according to the available documents, Ms. Price worked various jobs in sales and performed desk work. Additionally, the documents indicate she participated in more strenuous activities such as bicycling, hiking, tennis, yoga, and horseback riding. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Price and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb, can all produce an acceleration comparable to the subject incident.[44]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant

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42 Kai, Y., Oyama, M., Kurose, S., et al. (2001). "Neurogenic Thoracic Outlet Syndrome in Whiplash Injury." Journal of Spinal Disorders 14(6): 487-493.

43 Boezaart, A.P., Haller, A., Laduzenski, S., Koyyalanudi, V.B., Ihnatsenka, B., Wright, T., et al. '2010' Neurogenic thoracic outlet syndrome: A case report and review of the literature *International Journal of Shoulder Surgery* **4(2)**: 27-35.

44 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Price's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Price using peer-reviewed and generally accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 4, 2011, Ms. Catherine Price was the seat belted right front passenger of a 2006 Ford F350 traveling slowly near 731 3rd Street S in Kirkland, Washington that was contacted in the right rear side at low speed by a 1999 Dodge Grand Caravan.
2. The change in velocity was less than 5.9 miles per hour with an average acceleration less than 1.8g.
3. The acceleration experienced by Ms. Price was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Price's body rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint, passenger's side door interior, and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Price's claimed cervical sine biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Price's claimed bilateral thoracic outlet syndrome biomechanical failures. As such, a causal relationship between the subject incident and the bilateral thoracic outlet syndrome biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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June 18, 2014

Adrienne Harris, Esquire
Law Offices of Kenneth R. Scearce
1501 4th Avenue, Suite 420
Seattle, WA 98101

Re: *Price, Catherine v. Gordon Luna*
Supplemental Report
Claim No.: HEN2267 (WFS)
ARCCA Case No.: 2240-222

Dear Ms. Harris:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Ms. Catherine Price. This letter is meant to supplement my report of February 21, 2014, regarding Catherine Price. Since that time, I have had the opportunity to review and evaluate additional documents related to the subject incident on March 4, 2011. Furthermore, the additional documents do not change the opinions set forth in my previous analysis:

Additional Information Reviewed:

In the course of my supplemental analysis regarding Catherine Price, I reviewed the following additional materials:

- Deposition Transcript of Robin Price [May 6, 2014]
- Deposition Transcript of Catherine Ann Price [May 6, 2014]

Discussion:

Ms. Robin Price testified that she was looking forward and that upon impact her head went left, striking the driver's side window. Ms. Catherine Price testified that her head was turned approximately 30 degrees to the left and that upon impact her body moved forward, then left, followed by rightward and back. Both of these accounts are contrary to the actual motions of the subject incident. Due to the impact, the laws of physics dictate that the subjects would move toward the impact, which would be primarily rightward and slightly rearward. Scientific literature indicates that, provided the low accelerations of the event, no significant occupant motion would have occurred.[1,2] ARCCA, Inc. has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. This experimentation included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the experimentation. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion

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1 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA. Society of Automotive Engineers.

2 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA. Society of Automotive Engineers.

relative to the vehicle's interior. This is further supported by Ms. Robin Price's testimony that the subject Ford jerked due to the impact but did not change locations in the street other than her driving forward.

Additionally, the oral testimony by Robin Price and Catherine Ann Price is not consistent with the subject incident. The roadway was described as a cul-de-sac; however, the roadway simply dead-ends. A description of the vehicle orientations at the time of impact indicates the vehicles were parallel. This would alter the direction of impact, and the above described lateral movement would be inconsistent with a collinear impact. Also, in order to contact the vehicle while parallel, one of two scenarios would be necessary to occur. The vehicles would be well past the driveway, as time and space for the Luna to exit would be necessary. This would also indicate that the Luna vehicle in essence was "chasing" the Price vehicle and travelling at a greater rate of speed. A high rate of speed and excessive travel past the driveway would not be consistent with a normal driveway exit. The second scenario would be if the Luna vehicle did not exit from the driveway, but turned prior to entry onto the roadway, and travelled through shrubbery and potentially over a rock wall. This scenario is not consistent with any provided descriptions of the subject incident.

Conclusions:

Based upon the additional information reviewed, the opinions set forth in my report, dated February 21, 2014, have not changed and are further supported.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
PENGAD 800-631-6989
Probst 34
5-23-17 YhY

March 21, 2014

Brian Driscoll, Esquire
Barger Law Group, PC
4949 Meadows Road
Suite 620
Lake Oswego, WA 97035

Re: *Christensen, Mindi v. Matthew Severson and Gerald Severson*
ARCCA Case No.: 4202-013

Dear Mr. Driscoll:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Mindi Christensen. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony of Ms. Mindi Christensen and other available documents, on January 9, 2009, she was the seat belted driver of a 2006 Chevrolet Equinox traveling northeasterly through a parking lot area near Barnes and Noble at the Vancouver Plaza in Vancouver, Washington. Mr. Matthew Severson was the driver of a 2004 Chevrolet Silverado traveling directly behind the Chevrolet Equinox. The available documents reported that as the Chevrolet Equinox was slowing for traffic, it was struck from behind by the incident Chevrolet Silverado. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- One (1) grayscale photographic reproductions of the subject 2006 Chevrolet Equinox
- Eight (8) color photographic reproductions of the incident 2004 Chevrolet Silverado
- Lewis River Motor Co. Supplement of Record 1 with Summary estimate for the subject 2006 Chevrolet Equinox, February 12, 2009
- Repair estimate for the incident 2004 Chevrolet Silverado [April 28, 2009]
- Complaint for Damages, *Mindi Christensen v. Matthew Severson and Gerald Severson* [November 9, 2011]
- Plaintiff's Responses to Defendant's Interrogatories & Requests for Production, *Mindi Christensen v. Matthew Severson and Gerald Severson* [February 6, 2012]
- Plaintiff's Responses to Defendant's Second Interrogatories & Requests for Production, *Mindi Christensen v. Matthew Severson and Gerald Severson* [August 15, 2013]
- Plaintiff's Responses to Defendant Severson's Third Interrogatories, *Mindi Christensen v. Matthew Severson and Gerald Severson and State Farm Mutual Automobile Insurance Company* [February 13, 2014]
- Deposition Transcript of Mindi Christensen [April 16, 2013]
- Medical Records pertaining to Mindi Christensen
- VinLink data sheet for the subject 2006 Chevrolet Equinox
- Expert AutoStats data sheets for a 2006 Chevrolet Equinox
- VinLink data sheet for the incident 2004 Chevrolet Silverado
- Expert AutoStats data sheets for a 2004 Chevrolet Silverado

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Christensen claims were caused by the subject incident on January 9, 2009;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Christensen was occupying;
3. Determine Ms. Christensen's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Christensen's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Christensen attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
- Left Shoulder
  - Soft tissue biomechanical failure requiring surgery with Bankart repair

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

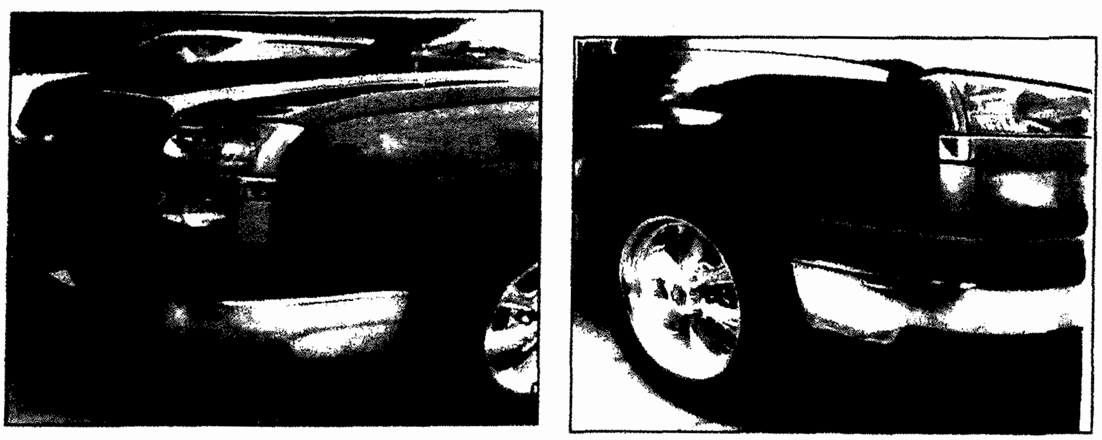
Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2006 Chevrolet Equinox and incident 2004 Chevrolet Silverado in association with accepted scientific methodologies.

The damage estimate of the subject Chevrolet Equinox indicated damage primarily to the rear bumper cover and trailer hitch receiver cover plate, which is consistent with the reviewed photograph (Figure 1). The photograph depicted damage to the hitch plate cover; however, there was no significant indentation/crush to the rear of the subject Chevrolet. Ms. Christensen testified the "Chevy emblem thing" on the tow hitch was dented, and the rear bumper was scraped on the driver's side.

Figure 1: Reproduction of a photograph of the subject 2006 Chevrolet Equinox

The damage estimate of the incident Chevrolet Silverado indicated damage primarily to the front bumper bar, which is consistent with the reviewed photographs (Figure 2). The photographs of the incident Chevrolet depicted a slight misalignment of the front face bar on the left side and damage to the license plate area.



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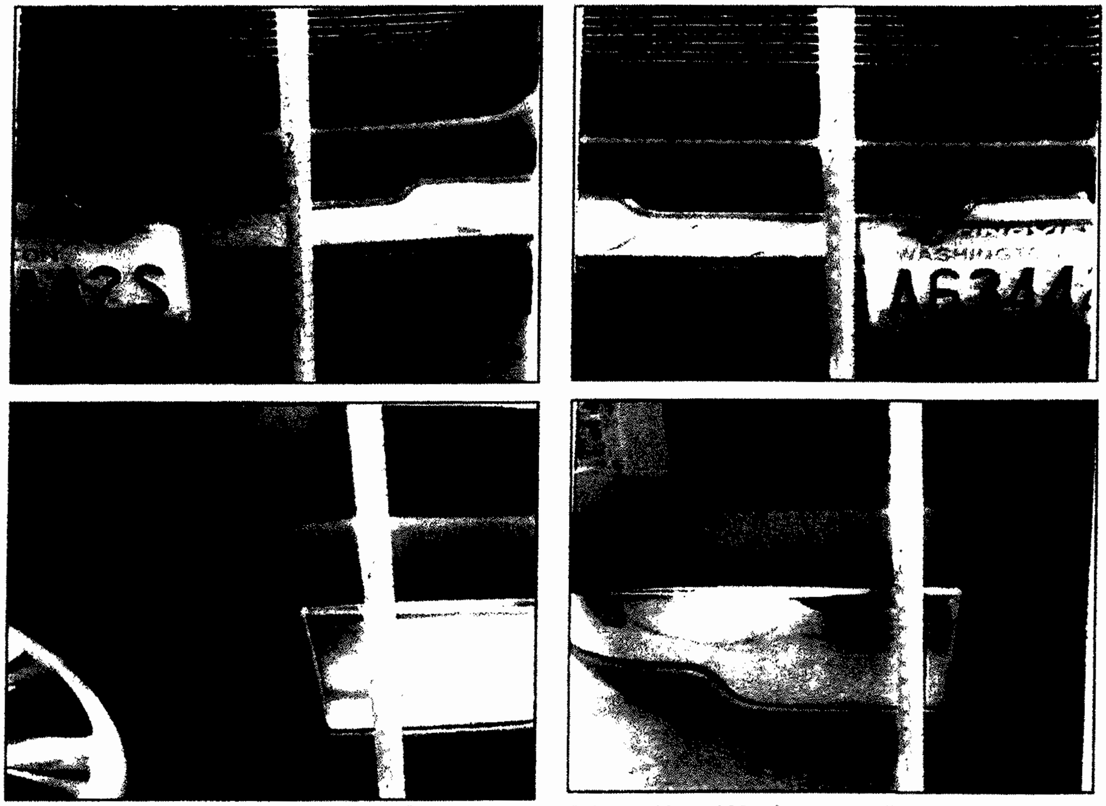

Figure 2: Reproductions of photographs of the incident 2004 Chevrolet Silverado

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Chevrolet Silverado can be used to resolve the loads sustained by the subject Chevrolet Equinox. That is, the loads sustained by the incident Chevrolet Silverado are equal and opposite to those of the subject Chevrolet Equinox.

The damage to the incident 2004 Chevrolet Silverado, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11,12] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a Chevrolet Silverado[13] in a 5 mile-per-hour frontal impact into a flat barrier. The test Chevrolet sustained damage to the front bumper face bar, left and right frame rail extension bumper mounting plates, left and right front frame rail ends, lower air deflector, and the left headlamp mounting panel. The primary damage to the incident Chevrolet was to the front bumper face bar. Thus, because the test Chevrolet Silverado in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater

11 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems (SAE 2003-01-0492). Warrendale, PA, Society of Automotive Engineers.

13 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2001 Chevrolet Silverado, April 2001.

compared to the severity of the subject incident and places the subject incident speed at or below 5 miles per hour for the incident Chevrolet Silverado.

The forces, velocities, and accelerations experienced during the incident by the subject Chevrolet Equinox were evaluated using the results of the above damage threshold speed change analysis along with the conservation of linear momentum.[14,15,16] Review of the vehicle damage, incident data, published literature, scientific analyses, the conservation of momentum, and my experience indicates an incident resulting in a Delta-V below 6.9 miles per hour for the subject Chevrolet Equinox. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.9 mile-per-hour impact is 2.1g.[17] By the laws of physics, the average acceleration experienced by the subject Chevrolet Equinox in which Ms. Christensen was seated was less than 2.1g. Further, this analysis is consistent with the an energy crush analysis of a 2006 Chevrolet Equinox and IIHS low-speed test for a 2002 Saturn Vue, essentially the same vehicle as the subject Chevrolet Equinox.[18,19,20,21,22,23,24,25]

The acceleration experienced due to gravity is 1g, which means that Ms. Christensen experiences 1g of loading while in a sedentary state. Therefore, Ms. Christensen experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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14 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.
15 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA. Society of Automotive Engineers.
16 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems (SAE 2003-01-0492). Warrendale, PA, Society of Automotive Engineers.
17 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.
18 Insurance Institute for Highway Safety Low-Speed Crash Test Report, 2002 Saturn Vue, July 2002.
19 Expert AutoStats datasheets for a 2002 Saturn Vue.
20 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
21 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
22 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
23 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
24 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
25 Tanner, C.B., Wiechel, J.F., et. al., (2001). Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations (SAE 2001-01-0891). Warrendale, PA, Society of Automotive Engineers.
26 Mow, V.C. and W.C. Hayes. (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance; the energy imparted to the Chevrolet Equinox in which Ms. Christensen was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Christensen's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

Ms. Christensen testified she was wearing the available three-point restraint system at the time of the subject incident. Prior to the incident, Ms. Christensen testified she was smoking and unaware of the impending collision. The medical records indicated that her left arm may have been resting on the window. Due to the impact, Ms. Christensen testified she remembered her body moving forward and the seat belt locked. Further, she testified that her head did not strike the headrest.

The laws of physics dictate that when the incident Chevrolet Silverado contacted the rear of the subject Chevrolet Equinox, the Equinox would have been pushed forward causing Ms. Christensen's seat to move forward relative to her body. This motion would result in Ms. Christensen moving rearward relative to the interior of the subject vehicle. The interaction between Ms. Christensen and the subject vehicle's interior would cause her body, specifically her torso and pelvis, to load into the seatback structures. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[27,28,29] Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Christensen would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Christensen was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[30,31]

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27 Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

28 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

29 Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

30 Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

31 Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A sprain is a biomechanical failure which occurs to a ligament (a thick, tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

During subject incident, the Chevrolet Equinox would be pushed forward and Ms. Christensen would have moved rearward relative to the vehicle, until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. Examination of an exemplar 2006 Chevrolet Equinox showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 32.5 inches in the full-down position and 34.75 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Christensen using her age (29 years), height (67 inches), and weight (240 lbs), she would have a normal seated height of 34.2 inches. Thus, the seat is tall enough to have prevented hyperextension of Ms. Christensen and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Additionally, Ms. Christensen noted that her headrest was well adjusted up to the back of her head. With the minimal accelerations and the neck motions within a normal physiological range, one would not expect traumatic biomechanical failures to the cervical spine.

Many researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[32,33,34,35,36] These peer-reviewed and generally accepted scientific investigations support the above conclusions. Test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Numerous test volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[37] Further studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma, and kinematics were inconsistent with the mechanism for cervical biomechanical failure. The above research describes the response of human volunteers subjected to rear impacts of comparable or greater severity to that experienced by Ms. Christensen in the subject incident.

Ms. Christensen testified that she is currently employed as a contractor for ADP which requires her to work at a computer. She worked as a polysomnographer at the Vancouver Clinic at the time of the subject incident. Additionally, she testified that she was able to carry groceries, play with her niece, and play with her dog. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[38,39] The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Funk et al. [40,41] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. Moreover papers by Ng et al.,[42,43] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations

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32 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

33 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

34 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

35 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

36 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine,* 29:979-987.

38 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation,* 42:25-30.

39 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

40 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

41 Funk, J.R., Cormier, J.M., et al., (2011) "Head and Neck Loading in Everyday and Vigorous Activities." *Annals of Biomedical Engineering,* 39(2):766-776.

42 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

43 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Christensen cannot be made.

Thoracic and Lumbar Spine

As stated above, a sprain is a biomechanical failure which occurs to a ligament (a thick, tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

During an event such as the subject incident, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

The subject incident had an average acceleration less than 2.1g. Ms. Christensen's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[44,45,46,47,48] Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[49,50,51,52] This

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[44] Gushue, D., B. Probst, et al., (2006) Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts. Safety 2006, Seattle, WA, ASSE.

[45] Nordin, M. and Frankel, V.H., (1989) Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[46] Adams, M.A., Hutton, W.C., (1982) Prolapsed Intervertebral Disc: A Hyperflexion Injury. *Spine*, 7(3):184-191.

[47] Schibye, B., Sogaard, K. et al., (2001) Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16:549-559.

[48] Gates, D., Bridges, A., Welch, T.D.J., et al., (2010) Lumbar Loads in Low to Moderate Speed Rear Impacts, (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

[49] Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

[50] Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma, and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 to 8 miles per hour.[53] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs, which measured spinal response to rear impact accelerations at severities greater than the subject incident.[54,55]

Ms. Christensen testified that on the day of the incident, she was cleaning her home including moving furniture and lifting sheets or glass from her living room tables. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[56] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[57] Studies by Rohlmann et al.[58,59,60] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight, can generate loads that are comparable or greater than those resulting from subject incident. Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off of a step.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces

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51 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

52 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

53 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

54 Gushue, D., B. Probst, et al. (2006). "Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts." Safety 2006, Seattle, WA, ASSE.

55 Gates, D., Bridges, A., Welch, T., et al., (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

56 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

57 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

58 Rohlmann, A., Claes, L.E., et al. (2001). "Comparison of Intradiscal Pressures and Spinal Fixator Loads for Different Body Positions and Exercises." Ergonomics 44 (8): 781-794.

59 Rohlmann, A., Petersen, R., et al. (2012). "Spinal loads during position changes." Clinical Biomechanics. 27: 754-758.

60 Rohlmann, A., Zander, T., et al. (2012). "Lifting up and laying down a weight causes high spinal loads." Journal of Biomechanics. 46: 511-514.

that exceeded the personal tolerance limits of Ms. Christensen, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Left Shoulder

According to a left shoulder MRI dated, July 8, 2009, there were findings consistent with a medium sized moderate thickness bursal partial tear of the anterior supraspinatus tendon, 50-70% thickness. A left shoulder operative report dated September 11, 2009, revealed findings of torn elements of the labral tissue as well as noting the shoulder was redundant and subluxed with forward flexion. The operative report further noted there was no SLAP lesion and the biceps tendon was stable.

There is no reason to assume that the claimed left shoulder biomechanical failures are causally related to the subject incident. Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." The supraspinatus runs laterally from the posterosuperior scapula to the head of the humerus. The supraspinatus tendon creates the connection between the supraspinatus muscle and the humeral head.[61] The biomechanical failure mechanism required to cause a supraspinatus tear involves loading through the upper arm that forcibly presses the humeral head against the acromion and coracoacromial ligament in the superior-posterior aspect of the glenoid fossa.[62,63,64] An acute labral tear requires loading directed into the glenoid fossa that generates a shearing force between the humeral head and glenoid labrum.[65,66,67] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[68] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[69,70]

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61 Netter, F.H. (1989) Atlas of Human Anatomy, Ciba-Geigy Corporation

62 Giaroli, E.L., Major, N.M., et al. (2005). "MRI of Internal Impingement of the Shoulder." American Journal of Radiology 185: 925-929.

63 Weaver, J.K., (1987). "Skiing-related Injuries to the Shoulder." Clinical Orthopaedics and Related Research 216: 24-28.

64 Warner, J.J., Higgins, L., Parsons, I.M., et al., (2001). "Diagnosis and Treatment of Anteriorsuperior Rotator Cuff Tears." Journal of Shoulder and Elbow Surgery 10(1): 37-46.

65 D'Alessandro, D.F., Fleischli, E., et al. (2000). "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.

66 Payne, L. Z., (1994). "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.

67 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008). "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.

68 Moore, K.L. and Dalley, A.F., (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

69 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

70 Braun, S., Kokmeyer, D., and Millett, P.J., et al., (2009). "Shoulder Injuries in the Throwing Athlete." Journal of Bone and Joint Surgery 91: 966-978.

During the subject incident, if motion was initiated, Ms. Christensen's body and extremities would have moved rearward relative to the subject vehicle's interior.[71,72,73] This rearward motion would have been supported and constrained by the seatback. Ms. Christensen's upper torso would have loaded into the seat structures and would have been well supported, as she testified occurred during the subject incident. Specifically, if there was rebound, the seat belt would have engaged Ms. Christensen's bony left clavicle and pelvis, limiting her motion during the subject incident. Ms. Christensen testified the seat belt rests between her shoulder and neck. The direction, force, and magnitude of the impact would not be sufficient to cause biomechanical failure. The low accelerations in the subject incident and the restraint provided by the seatback were such that any motion of Ms. Christensen's left shoulder would have been limited to well within the range of normal physiological limits.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than, that of the subject incident.[74,75,76,77] Again, Ms. Christensen testified that the day of the incident, she was doing laundry and cleaning her home. She continued to state that she was moving furniture and lifting glass tops off of end tables and the coffee table. Additionally, it should be noted that Ms. Christensen had discomfort in her left shoulder and arm due to lifting the table top glass.

As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder biomechanical failures of Ms. Christensen cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents and testimony, Ms. Christensen had previously worked as a contractor for ADP and was working as a polysomnographer at the Vancouver Clinic at the time of the subject incident. Ms. Christensen's jobs required her to work at a computer. Additionally, Ms. Christensen played with her dog, cleaned, and performed laundry duties. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Christensen and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving

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71 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

72 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). Rear-end Impact Testing with Human Test Subjects (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

73 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

74 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

75 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

76 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

77 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb, can all produce an acceleration comparable to the subject incident.[78]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Christensen's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Christensen using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On January 9, 2009, Ms. Mindi Christensen was the seat belted driver of a 2006 Chevrolet Equinox traveling through a parking area at the Vancouver Plaza in Vancouver, Washington, when the subject Chevrolet Equinox was contacted in the rear at low speed by a 2004 Chevrolet Silverado.
2. The severity of the subject incident was less than 6.9 miles per hour with an average acceleration less than 2.1g
3. The acceleration experienced by Ms. Christensen was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Christensen's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Christensen's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Christensen's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

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[78] Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

ARCCA

7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Christensen's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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PHONE 877-942-7222 FAX 206-547-0759
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EXHIBIT
Probst 35
5-23-17

April 21, 2014

Diana Ho, Casualty Specialist II
Safeco Insurance Company
PO Box 515097
Los Angeles, CA 90051-5097

Re: *Smith, Barbara v. Rosalie Gammelgaard*
Claim No.: 1553 8089 4039
ARCCA Case No.: 3271-251

Dear Ms. Ho:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Barbara Smith. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

Ms. Barbara Smith's testimony and other available documents indicate that on May 28, 2012, Ms. Smith was the seat belted driver of a 2007 Chevrolet Uplander traveling southbound on Rainier Avenue S at the intersection with S Henderson Street in Seattle, Washington. Ms. Rosalie Gammelgaard was the driver of a 1995 Toyota Previa traveling directly behind the Chevrolet. The available documents reported that as the Chevrolet was stopped at a red light, contact occurred between the front of the incident Toyota and rear of the subject Chevrolet. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) grayscale photographic reproduction of the subject 2007 Chevrolet Uplander
- Eleven (11) color photographic reproductions of the incident 1995 Toyota Previa
- Skeeter's Auto Rebuild, Inc. repair estimate for the subject 2007 Chevrolet Uplander [July 11, 2012]
- C&C Graphics Invoice for the subject 2007 Chevrolet Uplander [July 12, 2012]
- Safeco Insurance Company of Illinois estimate of record for the incident 1995 Toyota Previa [June 1, 2012]
- Recorded Statement Transcript of Barbara Smith [May 29, 2012]
- Recorded Statement Transcript of Rosalie Gammelgaard [May 29, 2012]
- Deposition Transcript of Barbara Smith [January 17, 2014]
- Medical Records pertaining to Barbara Smith
- VinLink data sheet for the subject 2007 Chevrolet Uplander
- Expert AutoStats data sheets for a 2007 Chevrolet Uplander
- VinLink data sheet for the incident 1995 Toyota Previa
- Expert AutoStats data sheets for a 1995 Toyota Previa

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the biomechanical failures that Ms. Smith claims were caused by the subject incident on May 28, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Smith was occupying;
3. Determine Ms. Smith's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Smith's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records and testimony indicate Ms. Smith attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2007 Chevrolet Uplander and incident 1995 Toyota Previa in association with accepted scientific methodologies.

The itemized repair estimate of the subject Chevrolet Uplander indicated damage primarily to the right side door shell, to align rear trailer hitch at the frame rails, and to check/adjust left side door shell, which is consistent with the reviewed photographs (Figure 1). The photographs of the subject Chevrolet did not depict significant structural crush/indentation. Ms. Smith testified the Chevrolet's rear bumper cracked, and there was damage to the hitch.

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[7] Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

[8] King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

[9] King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

[10] Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

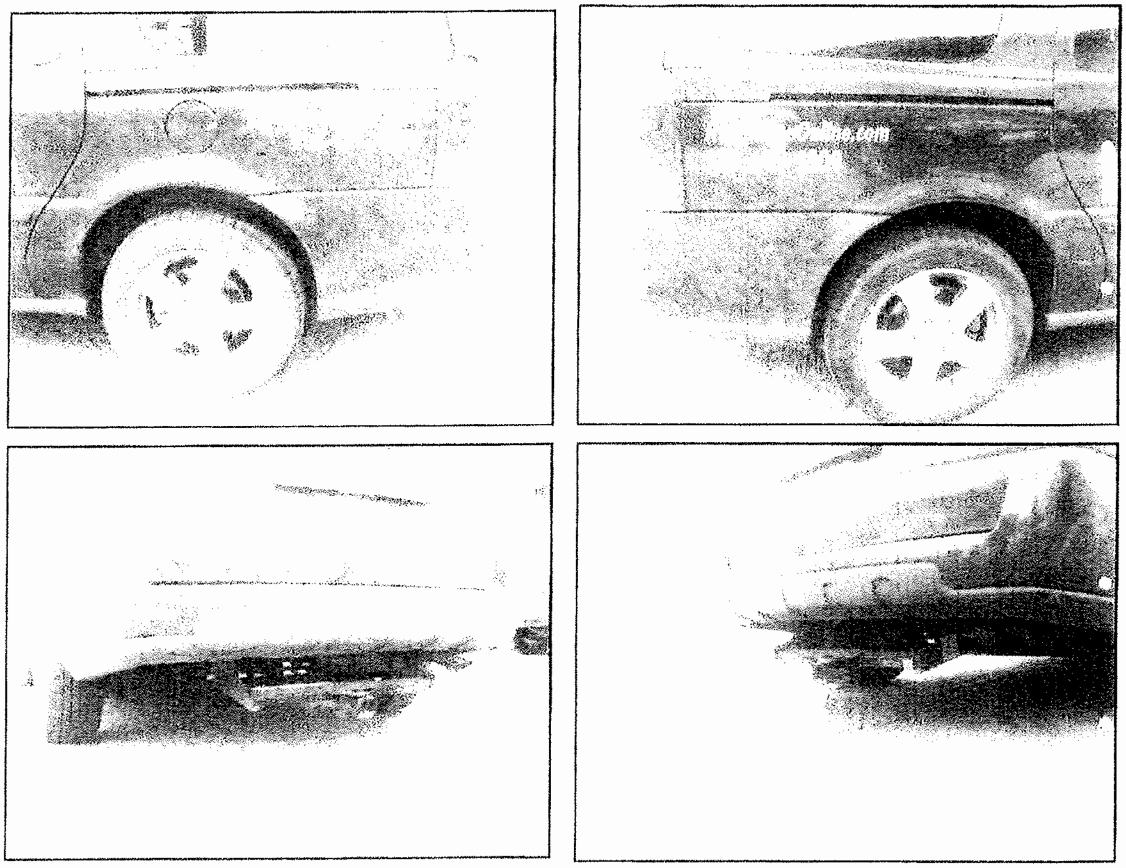

Figure 1: Reproductions of photographs of the subject 2007 Chevrolet Uplander

The damage estimate of the incident Toyota Previa indicated damage primarily to the front bumper cover, tie bar, and it required a floor pull; the repair estimate also noted prior damage to the grille, radiator (pushed in), hood dent, and core support. The photographs of the incident Toyota depicted damage to the front bumper cover, license plate, right headlamp assembly, and grille (Figure 2). Additionally, the photographs depict damage bias to the right side of the Toyota and scuff marks on the upper portion of the front bumper, which indicate that the Toyota's bumper went under the hitch on the subject Chevrolet. Further, according to Ms. Gammelgaard's statement, she stated it looked like the incident Toyota went under the subject Chevrolet's bumper.

Figure 2: Reproductions of photographs of the incident 1995 Toyota Previa

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Toyota Previa can be used to resolve the loads sustained by the subject Chevrolet Uplander. That is, the loads sustained by the incident Toyota are equal and opposite to those of the subject Toyota.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[11,12,13,14,15] Analyses of the photographs and geometric measurements of a 1995 Toyota Previa revealed the damage due to the subject incident. An energy crush analysis[16] indicates that a single 10 mile-per-hour flat barrier impact to the front of a Toyota Previa would result in significant and visibly noticeable angled crush across the entirety of the subject Toyota's front structure, with a residual angled crush of 4 inches.

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11 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

12 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

13 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

14 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

15 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

16 EDCRASH, Engineering Dynamics Corp.

Additionally, due to the underride situation, the crush would be double the amount calculated due to full engagement of the front structures. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile-per-hour Delta-V impact (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity to its post-impact velocity) than that of the subject incident.[17] The lack of significant structural crush to the entire front of the incident 1995 Toyota Previa indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour for the incident Toyota.

Further, The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Toyota Previa, defined by the photographic reproductions and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[18,19] The IIHS tested a 1996 Toyota Previa[20] in a 5 mile-per-hour frontal impact into a flat barrier. The test Toyota sustained damage to the front bumper reinforcement, front bumper cover, front bumper absorber, lower grille panel, and left and right front side member extensions. The primary damage to the subject Toyota was to the front bumper cover, tie bar, and required a floor pull. Thus, because the Toyota Previa in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed consistent with 5 miles per hour.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V significantly below 10 miles per hour and more consistent with 5 miles per hour for the subject Toyota Previa. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour and 5 miles-per-hour impact is 3.0g and 1.5g respectively.[21] By the laws of physics, the average acceleration experienced by the subject Chevrolet in which Ms. Smith was seated was less than 3.0g and more consistent with 1.5g. These results are consistent with empirical testing involving rear trailer hitches.[22]

The acceleration experienced due to gravity is 1g. This means that Ms. Smith experiences 1g of loading while in a sedentary state. Therefore, Ms. Smith experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events such as slowly climbing stairs, standing on one leg, or rising from a chair are capable of such forces.[23] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint

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17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

19 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems (SAE 2003-01-0492). Warrendale, PA, Society of Automotive Engineers.

20 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1996 Toyota Previa, December 1996.

21 Agaram, V., et al., (2000) Comparison of Frontal Crashes in Terms of Average Acceleration, (SAE 2000010880). Warrendale, PA. Society of Automotive Engineers.

22 Tanner, C.B., Wiechel, J.F., et. al., (2001). Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations (SAE 2001-01-0891). Warrendale, PA, Society of Automotive Engineers.

23 Mow, V.C. and W.C. Hayes. (1991) <u>Basic Orthopaedic Biomechanics</u>. New York, Raven Press.

load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Chevrolet Uplander in which Ms. Smith was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Smith's claimed biomechanical failures in the subject incident.

Kinematic Analysis:

Ms. Smith testified she was wearing the available three-point restraint system at the time of the subject incident. Prior to the collision, Ms. Smith testified that she was aware of the impending impact and braced the steering wheel with both hands. Additionally, the documents indicate Ms. Smith was facing forward at the time of impact. The laws of physics dictate that when the incident 1995 Toyota Previa contacted the rear of the subject 2007 Chevrolet Uplander, the Chevrolet would have been pushed forward causing Ms. Smith's seat to move forward relative to her body. This motion would result in Ms. Smith moving rearward relative to the interior of the subject vehicle. The interaction between Ms. Smith and the subject vehicle's interior would cause her body, specifically her torso and pelvis, to load into the seatback structures. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[24,25,26] Any rebound would have been well supported within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Smith would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Smith was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

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[24] Saczalski, K., S. Syson, et al., (1993) Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection, (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[25] Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

[26] Tencer, A.F., S. Mirza, et al., (2004) "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection 5(1):55-66.

[27] Mertz, H.J. and L.M. Patrick, (1967) Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions, (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[28] Mertz, H.J. and L.M. Patrick, (1971) Strength and Response of The Human Neck, (SAE710855). Warrendale, PA, Society of Automotive Engineers.

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

As stated above, during subject incident, the Chevrolet Uplander would be pushed forward, and Ms. Smith would have moved rearward relative to the vehicle until her motion was stopped by the seatback. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. A sprain is a biomechanical failure which occurs to a ligament (a thick, tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. Examination of an exemplar 2007 Chevrolet Uplander showed that the nominal height of the driver's seat with an unoccupied, uncompressed seat is 32.0 inches in the full-down position and 34.0 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, it does not need to be at the full seated height of the occupant. The top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Utilizing Ms. Smith's age (57 years), height (63 inches), and weight (150 lbs), an anthropomorphic regression of Ms. Smith indicates she would have a normal seated height of 32.0 inches. Thus, the seat is tall enough to have prevented hyperextension of Ms. Smith, and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. With the minimal accelerations and the neck motions within a normal physiological range, one would not expect traumatic biomechanical failures to the cervical spine.

Many researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[29,30,31,32,33] These peer-reviewed

29 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

30 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

31 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

and generally accepted scientific investigations support the above conclusions. Test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Numerous test volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[34] In further studies conducted at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma, and kinematics were inconsistent with the mechanism for cervical biomechanical failure. The above research describes the response of human volunteers subjected to rear impacts of comparable or greater severity than that experienced by Ms. Smith in the subject incident.

Ms. Smith testified that she was working as nurse assisting new mothers with breast feeding, bathing babies, and assessing newborns. Additionally, Ms. Smith testified she was capable of vacuuming, cleaning, doing the laundry, cooking, and doing yard work. Previous research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[35,36] The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Funk et al. [37,38] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. Moreover, papers by Ng et al.,[39,40] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and

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32 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

33 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

34 Ito, S., Ivancic, P.C., et al., (2004) "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" *Spine*, 29:979-987.

35 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42:25-30.

36 Vijayakumar, V., Scher, I., et al., (2006) Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living, (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

37 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

38 Funk, J.R., Cormier, J.M., et al., (2011) "Head and Neck Loading in Everyday and Vigorous Activities." *Annals of Biomedical Engineering*, 39(2):766-776.

39 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

40 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Smith cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents and testimony, Ms. Smith capable of working full time as a nurse, including picking up extra shifts. Further, she testified she would perform yard work, roller skate, and clean around her home. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Smith and can produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[41]

It is important to note that the peer-reviewed and generally accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Smith's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Smith using peer-reviewed and generally accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 28, 2012, Ms. Barbara Smith was the seat belted driver of a 2007 Chevrolet Uplander stopped at the intersection of Rainier Ave S and S Henderson Street in Seattle, Washington, when the subject Chevrolet was contacted in the rear at low speed by a 1995 Toyota Previa.
2. The severity of the subject incident was significantly below 10 miles per hour and more consistent with 5 miles per hour.
3. The average acceleration associated with the above listed severity is 3.0g and 1.5g respectively.
4. The acceleration experienced by Ms. Smith was within the limits of human tolerance and comparable to that experienced during various daily activities.

[41] Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs. Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

5. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Smith's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Smith's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
PENGAD 800-631-6989
Probst 36
5-23-17 MY

May 19, 2014

Kelsey Russell, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue, Suite 500
Seattle, WA 98101

Re: *Barker, Tanisha Shanee v. Kathryn Bartunek*
Claim No.: 714604445036
ARCCA Case No.: 2107-755

Dear Ms. Russell

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Tanisha Shanee Barker. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The available documents indicated on November 7, 2013, Ms. Sandra Murray was the driver of a 2012 Toyota Avalon traveling northbound on 12th Street near the intersection with James Street in Seattle, Washington. Ms. Tanisha Barker was the seat belted right front passenger in the Toyota Avalon. Ms. Kathryn Bartunek was the driver of a 2003 Mazda 6 traveling directly behind the Toyota Avalon. While the Toyota Avalon was stopped, contact occurred between the front of the incident Mazda 6 and rear of the subject Toyota Avalon.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Sixteen (16) color photographic reproductions of the subject 2012 Toyota Avalon
- Ten (10) color photographic reproductions of the subject 2003 Mazda 6
- Safeco Insurance Company Estimate of Record for the subject 2012 Toyota Avalon [November 12, 2013]
- Bankers Auto Rebuild & Towing Preliminary Supplement 1 with Summary for the subject 2012 Toyota Avalon [November 18, 2013]
- Safeco Insurance Company Supplement of Record 1 Summary for the subject 2012 Toyota Avalon [November 19, 2013]
- Safeco Insurance Company Estimate of Record for the incident 2003 Mazda 6 [November 12, 2013]
- Medical Records pertaining to Tanisha Barker
- VinLink data sheet for the subject 2012 Toyota Avalon
- Expert AutoStats data sheets for a 2012 Toyota Avalon
- VinLink data sheet for the incident 2003 Mazda 6
- Expert AutoStats data sheets for a 2003 Mazda 6
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

1. Identify the biomechanical failures that Ms. Barker claims were caused by the subject incident on November 7, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2012 Toyota Avalon;
3. Determine Ms. Barker's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Barker's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records indicated Ms. Barker attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain (noted as a Neck Sprain/strain in the medical records)
- Thoracic and Lumbar Spine
  - Sprain/strain (noted as a Back Sprain/strain in the medical records)
- Bilateral Shoulder
  - Soft tissue biomechanical failure such as a sprain/strain
- Post Concussive Syndrome or Closed Head Injury

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2012 Toyota Avalon and incident 2003 Mazda 6 in association with accepted scientific methodologies.

The estimate of record and preliminary supplemental repair record for the subject Toyota indicated damage primarily to the rear bumper cover, rear lower cover, and energy absorber, which is consistent with the reviewed photographs (Figure 1). Specifically, the reviewed photographs depicted two round license plate bolt punctures along with the indentation outline of the incident Mazda's front license plate. There was no significant indentation or crush depicted to any of the rear

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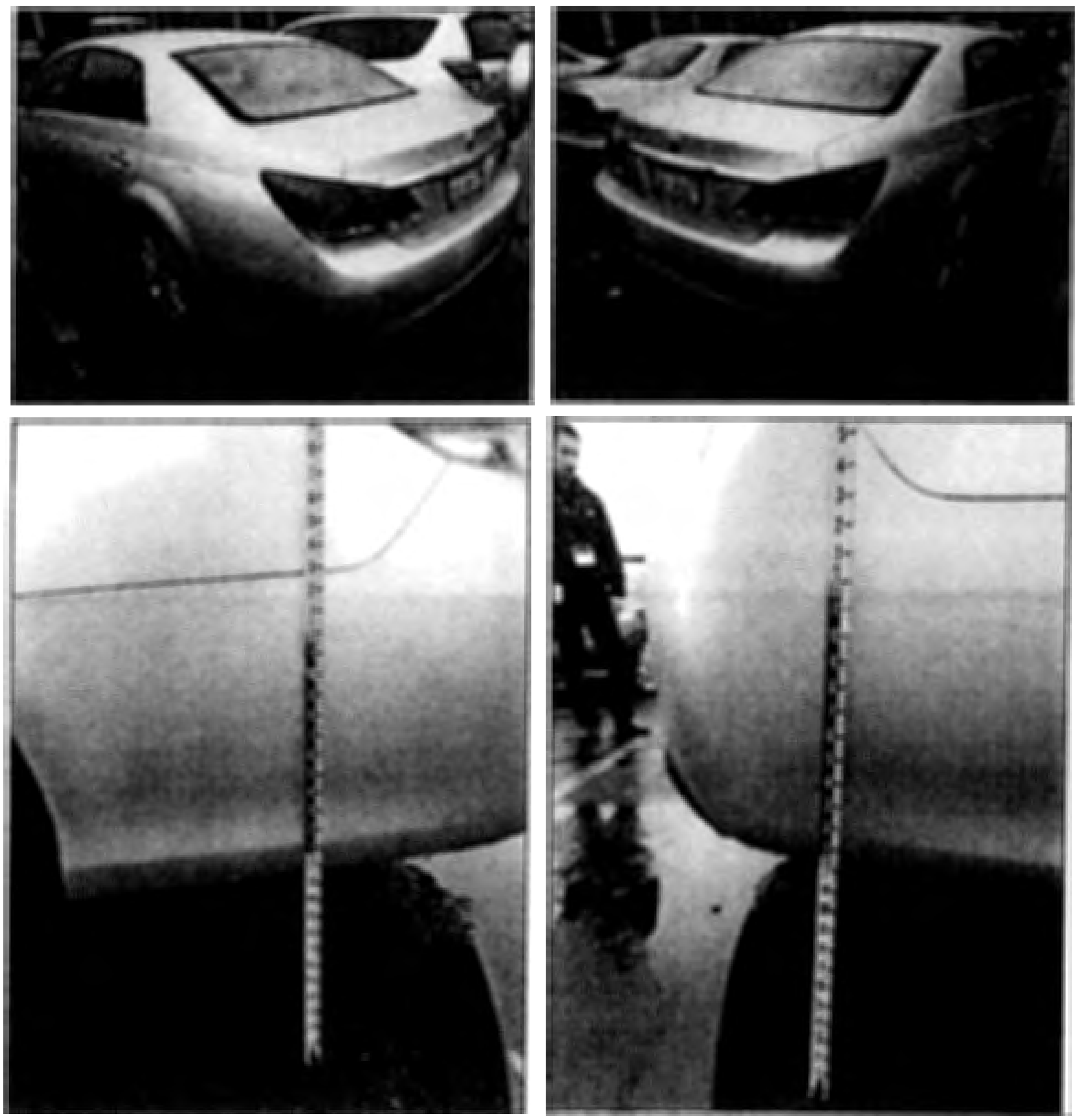
[9] King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

[10] Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

components of the subject Toyota. The AMR Seattle Patient Care Report within the medical records reported "no visible damage was sustained on either car".



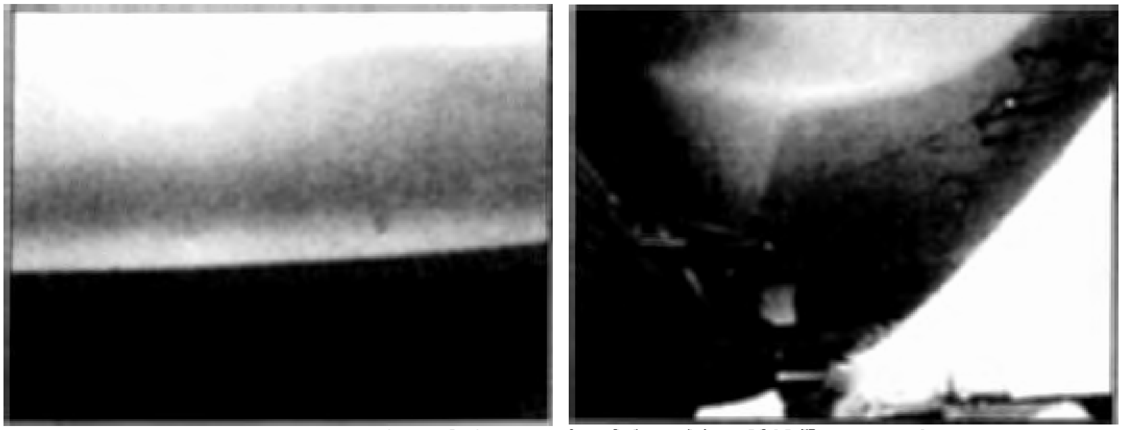


Figure 1: Reproductions of photographs of the subject 2012 Toyota Avalon

The estimate of record for the incident Mazda indicated damage primarily to the front bumper cover and license plate bracket, which is consistent with the reviewed photographs (Figure 2). Additionally, there was prior damage indicated to the left front bumper cover which consisted of paint scuffing near the left turn signal marker. Further, the reviewed photographs depicted a broken license bracket and front bumper cover scrapes/scuffs directly behind the license plate bracket. There was no significant indentation or crush depicted to any of the front components of the incident Mazda.

Figure 2: Reproductions of photographs of the incident 2003 Mazda 6

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Using this Law it is possible to analyze the incident Mazda 6 to determine the forces on the subject Toyota Avalon. The forces determined from analysis of the incident Mazda's frontal contact are therefore equal and opposite to those of the subject Toyota's rear contact.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident 2003 Mazda 6, defined by the photographic reproductions and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[11,12] The IIHS tested a 2003 Mazda 6[13] in a 5 mile-per-hour front impact into a flat barrier. The test Mazda sustained damage to the front bumper absorber and front grille. The primary damage to the incident Mazda was to the front bumper cover and license bracket. Thus, because the test Mazda 6 in the IIHS front impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is consistent with the severity of the subject incident and places the subject incident speed at or below 6.5 miles-per-hour for the incident Mazda 6.

The forces, velocities, and accelerations experienced during the incident by the subject Toyota Avalon were evaluated using the results of the above energy crush analysis along with the conservation of linear momentum.[14,15,16] Review of the vehicle damage, incident data, published literature, scientific analyses, the conservation of momentum, and my experience indicates an incident resulting in a Delta-V below 5.7 miles per hour for the subject Toyota. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5.7 mile-per-hour impact is 1.7g.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Toyota Avalon in which Ms. Barker was seated was less than 1.7g. Further, this analysis is consistent with energy crush analyses to the rear of the subject Toyota Avalon and front of the incident Mazda 6.[21,22,23,24,25]

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11 Siegmund, G.P., et al., (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

12 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

13 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2003 Mazda 6, September 2003.

14 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

15 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts*. (No. 950352). SAE Technical Paper.

16 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

21 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

22 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

23 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

24 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

25 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

The acceleration experienced due to gravity is 1g. This means that Ms. Barker experiences 1g of loading while in a sedentary state. Therefore, Ms. Barker experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events such as slowly climbing stairs, standing on one leg, or rising from a chair are capable of such forces. [26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance; the energy imparted to the Toyota Avalon in which Ms. Barker was seated was well within the limits of human tolerance.

Kinematic Analysis:

Ms. Barker's medical records indicate the subject Toyota Avalon was stopped when contact occurred to the rear of the vehicle. The laws of physics dictate that when the incident Mazda 6 contacted the rear of the subject Toyota Avalon, the Toyota would have been pushed forward causing Ms. Barker's seat to move forward relative to her body. This motion would result in Ms. Barker moving rearward relative to the interior of the subject vehicle, which would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback and seat bottom cushions. The low accelerations resulting from this collision would have caused little, or no, forward rebound of her body away from the seat back.[27,28,29] Ms. Barker's medical records indicated she was wearing the available three point restraint at the time of the incident. Any rebound would have been within the range of protection afforded by the available restraint system. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of Ms. Barker would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Barker was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[30,31]

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26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

27 Saczalski, K., Syson, S., et al. (1993). *Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection*. (No. 930346). SAE Technical Paper.

28 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

29 Tencer, A. F., Mirza, S., & Huber, P. (2004). A comparison of injury criteria used in evaluating seats for whiplash protection. *Traffic injury prevention*, *5*(1), 56-66.

30 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota Avalon would be pushed forward and Ms. Barker would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. The only general exposure for biomechanical failure of a properly seated and restrained occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. A sprain is a biomechanical failure which occurs to a ligament (a thick, tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat.

Examination of an exemplar 2006 Toyota Avalon showed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.5 inches in the full-down position and 33.75 inches in the full-up position. In order for a seatback to prevent an occupant from hyperextending over it, the top of the seat only needs to reach the base of the skull, as this is the area of the center of rotation of the skull. The seat bottom cushion will also compress approximately two inches under the load of an occupant. Based on an anthropometric regression of Ms. Barker's age (38 years), height (67 inches), and weight (255 lbs), Ms. Barker would have a normal seated height of 34.2 inches. Thus, the seat is tall enough to have prevented hyperextension of Ms. Barker, and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness.

Many peer-reviewed and generally accepted scientific investigations support the above conclusions. Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[32,33,34,35,36] The test subjects

[31] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

[32] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[37] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure. The above research describes the response of human volunteers subjected to rear impacts of comparable or greater severity to that experienced by Ms. Barker in the subject incident.

Ng et al.,[38,39] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Additional research by Funk et al.[40,41] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. Research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42,43] The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Barker cannot be made.

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33 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

34 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

35 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

36 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

38 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

39 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

40 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

41 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

42 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

43 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the thoracic and lumbar spine. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. Only with relative motion is significant loading to a body possible in an inertial, non-contact, loading scenario. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic and lumbar spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

The subject incident had an average acceleration less than 1.7g. Ms. Barker's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[44,45,46,47,48] Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[49,50,51,52] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma, and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 to 8 miles per hour.[53] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated

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[44] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[45] Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[46] Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

[47] Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

[48] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[49] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

[50] Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[51] Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

[52] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory, NBDL-86R006.

[53] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

ATDs, which measured spinal response to rear impact accelerations at severities greater than the subject incident.[54,55]

Studies by Rohlmann et al.[56,57,58] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable or greater than those resulting from subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[59] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[60]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Barker, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Bilateral Shoulders

There is no reason to assume that the claimed shoulder biomechanical failures are causally related to the subject incident. Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The supraspinatus, infraspinatus, subscapularis and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[61] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires

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54 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

55 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

56 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

57 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

58 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

59 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

60 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

61 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly injured during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[62,63]

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to or greater than that of the subject incident.[64,65,66,67] Ms. Barker's medical records indicated that she was independent with her daily activities. These activities would directly load Ms. Barker's shoulders to comparable or greater loads than the subject incident.

During the subject incident, Ms. Barker's body and extremities would have moved rearward relative to the subject vehicle's interior.[68,69,70,71] This rearward motion would have been supported and constrained by the seatback. Ms. Barker's upper torso would have loaded into the seat structures and, if there was rebound, the seat belt would have engaged Ms. Barker's bony right clavicle and pelvis, thus limiting her motion during the subject incident. The direction, force, and magnitude of the impact would not be sufficient to cause biomechanical failure. The low accelerations in the subject incident and the restraint provided by the seatback were such that any motion of Ms. Barker's shoulders would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported shoulder biomechanical failures of Ms. Barker cannot be made.

Concussion
Acute onset of concussion, or post concussive syndrome, requires that the brain tissue be stretched and/or strained beyond physiological limits.[72,73,74,75] The biomechanical failure mechanism required to cause a concussion is loading to the brain that causes stretching and/or straining of the brain

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62 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy. Fourth Edition, Lippencott Williams and Wilkins.
63 Braun, S., Kokmeyer, D., & Millett, P.J. (2009). Shoulder injuries in the throwing athlete. *The Journal of Bone & Joint Surgery*. *91*(4), 966-978.
64 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.
65 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.
66 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).
67 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.
68 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.
69 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.
70 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.
71 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.
72 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.
73 Gennarelli, T.A. (2003). Mechanisms of Brain Injury. *Journal of Emergency Medicine*, 11: 5-11.
74 Yoganandan, N., Gennarelli, T.A., et al. (2009). Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes. *Journal of Trauma*, 66(2): 309-315.
75 Gennarelli, T.A., Thibault, L.E., and Ommaya, A.K. (1971). *Pathophysiologic Responses to Rotational and Translational Accelerations of the Head*. (No. 720970). SAE Technical Paper.

tissue beyond physiological limits. These biomechanical failures are associated with substantial impulsive or impact loads applied to the head.[76] The Head Injury Criterion (HIC) has been adopted by the United States federal government as the standard criterion for the determination of risk of a head biomechanical failure for the Federal Motor Vehicle Safety Standards (FMVSS). In brief, HIC is calculated from resultant accelerations at the center of gravity of the head (based upon three orthogonal directions) that are optimized over the duration of an impact. FMVSS 201, titled Occupant Protection in Interior Impact, specifies requirements to afford impact protection for occupants.[77] More specifically, FMVSS 201 is related to the likelihood of biomechanical failure resulting from occupant head contact with the interior of a vehicle. FMVSS 201 dictates that when the interior of a vehicle is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, HIC(d), an acronym for Head Injury Criterion (dummy), should not exceed 1000 for any two points in time during the impact which are separated by not more than a 36 millisecond time interval. FMVSS 201 further dictates that when a seatback is impacted by a free-motion Hybrid III headform at a speed of 15 miles per hour, the deceleration of the headform shall not exceed 80g continuously for more than 3 milliseconds. This requirement is consistent with previous research published by Ono et al. that investigated the human head impact tolerance and the threshold for concussion.[78]

FMVSS 202a, titled Head Restraints, specifies new requirements for head restraints to reduce the frequency and severity of head and neck biomechanical failures in rear-end and other collisions.[79] More specifically, FMVSS 202a specifies that during dynamic rear impact testing at accelerations of approximately 9.4g, HIC should not exceed 500 for any two points in time during the impact which are separated by not more than a 15-millisecond time interval.

The subject incident had an average acceleration below 1.7g. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[80,81] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be a peak 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

The subject incident lacked the energy necessary to cause Ms. Barker's claimed head biomechanical failure.[82] Ms. Barker's body and head would have moved rearward relative to the Toyota's interior. As stated above, Ms. Barker's headrest was tall enough to provide her with proper support and limit her head motion. Additionally, Ms. Barker's medical records indicated her head struck the headrest. Scientific research demonstrates that this motion and contact would have been maintained within

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76 Goldsmith, W. (2001). The State of Head Injury Biomechanics: Past, Present, and Future: Part 1. *Critical Reviews in Biomedical Engineering*. 29(5 & 6): 441-600.

77 Federal Motor Vehicle Safety Standard 571.201. Occupant Protection in Interior Impact.

78 Ono. K., Kikuchi. A., et al. (1980). Human Head Tolerance to Sagittal Impact Reliable Estimation Deduced from Experimental Head Injury Using Subhuman Primates and Human Cadaver Skulls. (SAE 801303). Warrendale, PA, Society of Automotive Engineers.

79 Federal Motor Vehicle Safety Standard 571.202a. Head Restraints.

80 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

81 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

82 Yoganandan, N., Gennarelli, T.A., et al. (2009). Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes. *Journal of Trauma, 66*(2): 309-315.

human tolerance.[83,84] Further peer-reviewed and generally accepted methodologies also demonstrate that the loading during the subject incident was insufficient to generate the biomechanical failure mechanisms responsible for causing a concussive biomechanical failure to Ms. Barker during the subject incident.[85,86,87]

Scientific data collected from various research programs support these conclusions. Human volunteers have frequently been exposed to rear-end impacts at severity levels comparable to and greater than that of the subject incident.[88,89, 90,91] Results demonstrated that occupants moved rearward while their heads interacted with the head restraint. None of the volunteers reported head/brain trauma, and data collected demonstrated that the biomechanical failure mechanism required to cause a concussion were not present. Additional research has involved cadavers and anthropomorphic test devices (ATDs).[92,93,94] Further, this subject incident had an average acceleration of less than 1.9g. Ng et al.,[95,96] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Funk et al.[97,98] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature, the subject incident created accelerations that were well within human tolerance and were

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83 Gennarelli, T.A., Pintar, F.A., and Yoganandan, N. (2003). Biomechanical Tolerances for Diffuse Brain Injury and a Hypothesis for Genotypic Variability in Response to Trauma. *Annu Proc Assoc Adv Automot Med,* 47:624-628.

84 Nusholtz, G. S., Lux, P., Kalker, P., et al. (1984). *Head Impact Response – Skull Deformation and Angular Accelerations.* (No. 841657). SAE Technical Paper.

85 Fijalkowski, R.J., Stemper, B.D., Pintar, F.A., et al. (2007). Influence of Angular Acceleration Pulse Duration on Functional Outcomes Following Mild Diffuse Brain Injury. *Proceedings of the International Conference on the Biomechanics of Impact.* 161-171.

86 Hodgson, V.R., Thomas, L.M., Gurdjian, E.S., et al. (1969). *Advances in Understanding of Experimental Concussion.* (No. 690796). SAE Technical Paper.

87 McIntosh, A.S., Kallieris, D., Mattern, R., et al. (1993). *Head and Neck Injury Resulting from Low Velocity Direct Impact.* (No. 933112). SAE Technical Paper.

88 Kumar, S., Ferrari, R., Narayan, Y. (2005). Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion: Summary of Research. *Clinical Biomechanics.* 20: 553-568.

89 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

90 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

91 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

92 Welch, T.D.J., Bridges, A.W., Gates, D.H., et al. (2010). *An Evaluation of the BioRID II and Hybrid III During Low- and Moderate-Speed Rear Impact.* (No. 2010-01-1031). SAE Technical Paper.

93 Hu, A.S., Bean, S.P, and Zimmerman, R.M. (1977). *Response of Belted Dummy and Cadaver to Rear Impact.* (No. 770929). SAE Technical Paper.

94 Welcher, J.B., Szabo, T.J., and Voss, D.P. (2001). *Human Occupant Motion in Rear-End Impacts: Effects of Incremental Increases in Velocity Change.* (No. 2001-01-0899). SAE Technical Paper.

95 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42,* 410.

96 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42,* 25-30.

97 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

98 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

comparable to accelerations applied during daily activities. Therefore, the subject incident was within Ms. Barker's personal tolerance. In addition, the loads associated with the subject incident were not applied in the proper manner or with sufficient magnitude to generate the biomechanical failure mechanism necessary for her diagnosed head biomechanical failures. As this crash event did not apply loads of sufficient magnitude to exceed Ms. Barker's personal tolerance and the necessary biomechanical failure mechanism was not created, causation between the subject incident and her claimed head biomechanical failures cannot be established.

Personal Tolerance Values

As noted previously, according to the available documents, Ms. Barker was independent with her daily activities. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Barker and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb, can all produce an acceleration comparable to the subject incident.[99]

It is important to note that the peer-reviewed and generally accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Barker's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Barker using peer-reviewed and generally accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 7, 2013, Ms. Tanisha Barker was the seat belted right front passenger of a 2012 Toyota Avalon traveling northbound on 12th Street in Seattle, Washington, when the subject Toyota was contacted in the rear at low speed by a 2003 Mazda 6.
2. The severity of the subject incident was below 5.7 miles per hour with an average acceleration less than 1.7g
3. The acceleration experienced by Ms. Barker was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Barker's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

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99 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).* (No. 960654). SAE Technical Paper Series.

5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Barker's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Barker's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Barker's claimed bilateral shoulder biomechanical failures. As such, a causal relationship between the subject incident and the bilateral shoulder biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Barker's claimed head biomechanical failures. As such, a causal relationship between the subject incident and the head biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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November 24, 2014

Claudia Shannon
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Ave, Suite 500
Seattle, WA 98101

Re: *Wilson, David v. David Green*
ARCCA Case No.: 2107-800
Your Claim No.: 9820 9846 4041

Dear Ms. Shannon:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces experienced by David Wilson. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available and the claimed injuries of the vehicle occupants, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the American Society of Safety Engineers, the American Society of Mechanical Engineers, and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

Incident Description:

According to the reviewed documents, on May 17, 2011, David Wilson was the driver of a 2011 Dodge Challenger and reportedly stopped suddenly for traffic. A 2010 Toyota Corolla, driven by David Green, traveling behind the subject Dodge Challenger failed to stop in time, and the front of the Toyota contacted the rear of the subject Dodge Challenger. No airbag in the either vehicle deployed, and the vehicles did not require towing from the incident scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Safeco Insurance Company of Illinois Estimate of Record for the subject Dodge Challenger, written by Jason McLean, May 18, 2011
- Safeco Insurance Company of Illinois Estimate of Record for the incident Toyota Corolla, written by Jason McLean, May 23, 2011
- Eighteen (18) color digital photographic reproductions of the subject Dodge Challenger
- Fourteen (14) color digital photographic reproductions of the incident Toyota Corolla
- VinLink data sheet for the subject 2011 Dodge Challenger
- Expert AutoStats data sheets for a 2011 Dodge Challenger
- VinLink data sheet for the incident 2010 Toyota Corolla
- Expert AutoStats data sheets for a 2010 Toyota Corolla

Damage and Incident Severity:

The photographs of both vehicles were utilized in analyzing the incident severity. There was cosmetic damage to both vehicles.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Toyota Corolla can be used to resolve the loads sustained by the subject Dodge Challenger. That is, the loads sustained by the incident Toyota are equal and opposite to those of the subject Dodge.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Toyota, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[4] The IIHS tested a 2010 Toyota Corolla. In a 6.1 mile-per-hour front impact into a flat barrier, the test Toyota had damage to the bumper cover, energy absorber, reinforcement hood, and both headlamps. The damage noted to the incident Toyota was to the front bumper cover and license bracket. Thus, the severity of the IIHS impact is greater than the severity of the subject incident and places the subject incident speed at or below the test speed of 6.1 miles-per-hour. Utilizing conservation of momentum, the change in velocity for the subject Dodge is 4.3 miles per hour.

[4] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

The above analysis is consistent with numerous staged low-speed impact tests indicating that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[5] Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 4.3-mile-per-hour impact is 2.3g.[6] Review of the available data, engineering analyses, and my experience indicates an incident resulting in minimal accelerations to the subject Dodge in which Mr. Wilson was seated.

The acceleration experienced due to gravity is 1g. This means that David Wilson experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by him in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events such as slowly climbing stairs, standing on one leg, or rising from a chair are capable of such forces.[7] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 2.3g associated with the subject incident.[8]

In recent papers by Ng et al.,[9,10] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender). As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Research by Funk et al.[11] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to David Wilson in the subject Dodge was well within the limits of

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[5] West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

[6] Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

[7] Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

[8] Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

[9] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

[10] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

[11] Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

Kinematic Analysis:

According to the laws of physics, when contact between the Dodge and the Toyota occurred, had there been enough energy transferred to cause any motion, the Dodge would have been accelerated and pushed forward. This would have resulted in the vehicle moving forward relative to David Wilson, causing his body to load into the seat and seat back, thus coupling his motion to the vehicle. One would not expect hyperextension of the head and neck in the subject incident. Szabo et al.,[12] McConnell et al.,[13] and West et al.[14] have shown that hyperextension does not occur at energy levels such as those that were experienced in the subject incident. Finally, the low accelerations resulting from this collision would have caused little, or no, forward rebound of his body away from the seat back.[15,16,17] Any rebound would have been within the range of protection afforded by the available restraint system.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On July 26, 2013, David Wilson was the driver of the subject Dodge Challenger, which was contacted in the rear by a Toyota Corolla at low speed.
2. The severity of the subject incident is consistent with a Delta-V at or below 5 miles per hour, with a maximum acceleration below 2.3g for the subject Dodge in which David Wilson was seated.
3. Had there been enough energy transferred to cause any motion, the Dodge would have been accelerated and pushed forward coupling Mr. Wilson's motion to the vehicle, causing his body to load into the seat and seat back.
4. The energy imparted to David Wilson in the subject Dodge was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

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12 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

13 McConnell WE, Howard RP, Guzman HM, Bomar JB, Raddin JH, Benedict JV, Smith HL, and Hatsell CP (1993). *Analysis of Human Test subject Kinematic Responses to Low Velocity Rear End Impacts* (SAE 930889). Warrendale, PA: SAE.

14 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

15 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

16 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

17 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." Traffic Injury Protection **5**(1): 55-66.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME, Senior Biomechanist

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January 16, 2015

Kelsey Farnam, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Ada Bezhenar v. Dolores Bussabarger*
Claim Number: 287381954039
ARCCA Case No.: 3271-259

Dear Ms. Farnam:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Ada Bezhenar. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

EXHIBIT E

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony and other available documents, on March 13, 2011, Ms. Ada Bezhenar was the seat belted driver of a 2000 Mercedes-Benz S430 traveling south in the left lane of Interstate 5, near exit 103 in Tumwater, Washington. Ms. Bezhenar stated she moved her vehicle to the right to allow a vehicle to pass. Dolores Bussabarger was the driver of a 2004 Chevrolet Impala traveling north in the southbound lanes of Interstate 5. The Bussabarger vehicle contacted a 2008 Toyota Tacoma driven by Deepti Sharma. Ms. Bezhenar stated her vehicle was not contacted by the other vehicles, however, her vehicle ran over debris from the incident, including bumpers and tires. The airbags for the subject Mercedes-Benz did not deploy and the vehicle did not require towing.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Seven (7) color photographic reproductions of the subject 2000 Mercedes-Benz S430
- Fourteen (14) color photographic reproductions of the incident 2004 Chevrolet Impala [March 16, 2011]
- Nine (9) color photographic reproductions of the incident 2008 Toyota Tacoma [March 16, 2011]
- Estimate of Record for the subject 2000 Mercedes-Benz S430 [April 25, 2011]
- Supplement of Record 1 with Summary for the subject 2000 Mercedes-Benz S430 [June 14, 2011]
- Estimate of Record for the incident 2004 Chevrolet Impala [March 16, 2011]
- Estimate of Record for the incident 2008 Toyota Tacoma [March 16, 2011]
- Medical records and reports pertaining to Ada Bezhenar
- Deposition Transcript of Ada L. Bezhenar [July 23, 2014]
- VinLink data sheet for the subject 2000 Mercedes-Benz S430
- Expert AutoStats data sheets for a 2000 Mercedes-Benz S430
- VinLink data sheet for the incident 2004 Chevrolet Impala
- Expert AutoStats data sheets for a 2004 Chevrolet Impala
- VinLink data sheet for the incident 2008 Toyota Tacoma
- Expert AutoStats data sheets for a 2008 Toyota Tacoma
- ARCCA inspection of exemplar Mercedes-Benz vehicles [January 7, 2015]

ARCCA

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Bezhenar claims were caused by the subject incident;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Bezhenar was occupying;
3. Determine Ms. Bezhenar's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Bezhenar's responses to the subject incident;
5. Evaluate Ms. Bezhenar's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Bezhenar has reported the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
    - C5-C6 joint dysfunction
- Thoracic Spine
    - Sprain/strain
    - Subluxation

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

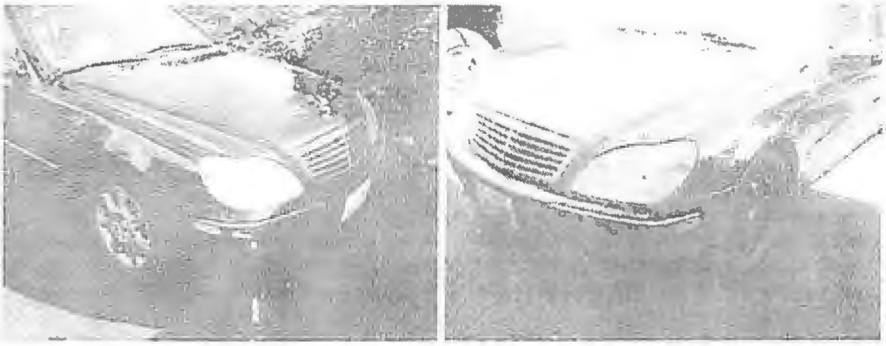

Figure 3. Front of the subject Mercedes-Benz

While Ms. Bezhenar noted her vehicle ran over bumpers and tires, this would not have occurred. As noted in Figures 1 and 2, the bumpers of both the Chevrolet and Toyota remained attached to the vehicles. The left front wheel assembly was displaced from the incident Chevrolet and the left rear tire was displaced on the incident Toyota. The front and undercarriage of the subject Mercedes-Benz, based upon measurements of exemplar Mercedes-Benz vehicles, would not allow for a tire or wheel the sizes of the incident tire and wheel assembly to go under the Mercedes-Benz. The most one would expect is the debris to wedge between the roadway and the front bumper of the subject Mercedes. Therefore, only minor debris could have been run over and this debris would have been less than an approximate height of 4 inches.

For the above noted reasons, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[11] This testing has shown that no significant lateral accelerations occur. Testing has shown speed bump impacts and curb drops of 6.26 inches produce accelerations of less than 1g.

The acceleration experienced due to gravity is 1g. This means that Ms. Bezhenar experiences 1g of loading while in a sedentary state. Therefore, Ms. Bezhenar experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by Ms. Bezhenar in her daily life would have increased the loading to her body beyond the sedentary 1g. Ms. Bezhenar noted that she had just cleaned after her sister's engagement party, could perform household chores and travel. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[12] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the average acceleration associated with the subject incident.[13]

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11 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop offs, Loose Gravel, Bumps and Potholes). SAE Technical Paper Series #960654.

12 Mow, V.C. and W.C. Hayes (1991) Basic Orthopaedic Biomechanics, New York, Raven Press.

13 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences Instrumentation*, 42: 25-30.

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance, the energy imparted to the Mercedes-Benz in which Ms. Bezhenar was seated was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism for Ms. Bezhenar's claimed biomechanical failures in the subject incident.

Purpose of Seat Belt Restraints:

The need to restrain occupants within vehicles to provide protection during crashes has been well known for many years in the occupant crash protection area in general, and in the automobile industry in particular. This protection has traditionally been provided through the use of seat belts, which have a threefold purpose:[14]

1) To prevent occupant ejection from the vehicle;
2) To couple the occupant to the vehicle in order to take advantage of the energy management properties provided by the crush of the vehicle's structure, thereby allowing the occupant to "ride down" the forces produced during the crash; and
3) To minimize the "second collision" of the occupant against the interior surfaces of the vehicle.

Kinematic Analysis:

According to her testimony, Ms. Bezhenar was wearing the available three-point restraint system at the time of the subject incident. The laws of physics dictate that when the incident Mercedes-Benz contacted the debris, the Mercedes-Benz would have been decelerated and lifted vertically. Fundamental laws of physics dictate that, at contact with the debris, Ms. Bezhenar was traveling at the same speed and in the same direction as the Mercedes-Benz. The initial contact with the debris would decelerate the Mercedes-Benz longitudinally and accelerated the vehicle vertically. The basic laws of physics dictate that, upon impact with the debris, Ms. Bezhenar continued to move at the pre-impact speed of the Mercedes-Benz, while the vehicle was redirected. Therefore, Ms. Bezhenar would tend to move forward and downward relative to the interior of the vehicle. The low accelerations in the subject incident and the restraint provided by the seat belt system, then, were such that any motion of Ms. Bezhenar would have been limited to well within the range of normal physiological limits.

Findings:

1. On March 13, 2011, Ms. Ada Bezhenar was the seat belted driver of a 2000 Mercedes-Benz S430 that ran over motor vehicle debris.
2. The change in velocity was less than 2.3 miles per hour with a peak acceleration less than 1g.
3. The acceleration experienced by Ms. Bezhenar was within the limits of human tolerance, the personal tolerance levels of Ms. Bezhenar and comparable to that experienced during various daily activities.

[14] NHTSA Standardized Child Passenger Safety Training Program: Instructor Guide, Summer, 2001.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Bezhenar was well within the limits of human tolerance and well below the acceleration levels that they experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[15,16]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the available medical documents, Ms. Bezhenar was diagnosed with a cervical sprain/strain.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type of biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. As described previously, the vehicle interaction would have caused longitudinal deceleration and vertical acceleration of the subject Mercedes-Benz. Had the forces generated been sufficient to overcome Ms. Bezhenar's muscle reaction forces, her body would have moved forward and downward relative to the Mercedes-Benz's interior. Ms. Bezhenar's cervical spine would have been subjected to a controlled degree of flexion during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact.[17] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head

[15] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[16] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

[17] Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

motion was predominately self-limiting.[18] As a result, Ms. Bezhenar's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[19]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations. Nielsen et al.[20] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers. The Delta-V of the bullet vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic cervical spine injuries were reported. Siegmund and Williamson[21] investigated frontal impacts using human volunteers. The Delta-V of the striking vehicle was comparable to that associated with the subject incident, and no chronic cervical injuries were reported. Several researchers have used cadavers to assess cervical spine injury potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical injury are greater than that associated with the subject incident.[22,23] Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[24] None of the participants reported any chronic cervical injuries. Arbogast et al.[25] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or injury to any participants. Research by Weiss et al.[26] demonstrated that human subjects have been subjected to frontal impact acceleration levels up to 16g without any permanent physiological changes to their cervical spine and only minor neck stiffness.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[27,28] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As

18 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

19 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

20 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

21 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

22 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

23 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

24 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

25 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

26 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

27 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415

28 Ng, Tp, Bussone, WR, Duma, SM, Kress, TA, (2006), "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30

this crash event did not create the required injury mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine injuries of Ms. Bezhenar cannot be made.

Thoracic and Lumbar Spine

There is no reason to assume that the claimed thoracic and lumbar spine biomechanical failures are causally related to the subject incident. In an event of the type seen here, the pelvis, and thoracic, lumbar, and sacroiliac spines of a driver are limited in motion by the restraint system. The seatbelt would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatbelt system would also distribute the restraint forces over the torso and hips, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The seatbelt system would not allow for hyperflexion of Ms. Bezhenar's torso. An occupant's body reacts as a whole, meaning the back moves as a whole unit forward with little flexion, unless one portion of the spine is supported with another portion unsupported. There would be a greater movement on Ms. Bezhenar's pelvis and spine when she sits down in a chair than would be produced in the subject incident.

While restrained, live human subjects' torsos have regularly been exposed to frontal g levels up to approximately 40g with no acute trauma, only transient, short term soreness.[29] The subject incident had peak accelerations of 1g. Previous research has shown that thoracic spine, lumbar spine, and hip accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30],[31]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The accelerations created by the subject incident were well within the limits of human tolerance. For these reasons, a causal link between the subject incident and the thoracic or lumbar spine biomechanical failures claimed by Ms. Bezhenar cannot be made.

Personal Tolerance Values

As noted previously, according to her records, Ms. Bezhenar could clean, perform household chores, and travel. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Bezhenar and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal

29 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

30 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities" *Biomedical Sciences Instrumentation* 42: 410-415.

31 Bergmann, G., Deuretzbacher, G., et al. (2001). "Hip Contact Forces and Gait Patterns from Routine Activities." *Journal of Biomechanics* 34: 859-871.

relationship between Ms. Bezhenar's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Bezhenar using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 13, 2011, Ms. Ada Bezhenar was the seat belted driver of a 2000 Mercedes-Benz S320 that ran over motor vehicle debris.
2. The change in velocity was less than 2.3 miles per hour with a peak acceleration less than 1g.
3. The acceleration experienced by Ms. Bezhenar was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Bezhenar's body forward and downward. These motions would have been limited and well controlled by the seatbelt and seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Bezhenar's claimed cervical spine biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Bezhenar's claimed thoracic or lumbar spine biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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EXHIBIT
PENGAD 800-631-6989
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February 9, 2015

Theodore Miller, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Irons, Lonnie v. Lily Smolan*
Claim No.: 2342 8191 5041
ARCCA Case No.: 2107-817

Dear Mr. Miller:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Lonnie Irons. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The available documents reported on January 25, 2013, Ms. Lori Irons was the driver of a 1998 Pontiac Sunfire traveling westbound on Emerson Street (40th Street Ct W) in Fircrest, Washington. Mr. Lonnie Irons was the seat belted right front passenger of the Pontiac Sunfire. Ms. Lily Smolan was the driver of a 2005 Toyota Prius traveling directly behind the Pontiac. The available documents indicated that as the Pontiac stopped for traffic, the Toyota was unable to stop in time. As a result, contact occurred between the front of the Toyota and the rear of the Pontiac.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 1998 Pontiac Sunfire
- Eight (8) color photographic reproductions of the incident 2005 Toyota Prius
- Precision Collision – Tacoma Estimate of Record for the subject 1998 Pontiac Sunfire [January 29, 2013]
- First National Insurance Company of America Estimate of Record for the incident 2005 Toyota Prius [February 4, 2013]
- Deposition Transcript of Lonnie D. Irons, *Irons v. Smolan* [September 4, 2014]
- Deposition Transcript of Lily Smolan, *Irons v. Smolan* [September 4, 2014]
- Medical Records pertaining to Lonnie Irons
- VinLink data sheet for the subject 1998 Pontiac Sunfire
- Expert AutoStats data sheets for a 1998 Pontiac Sunfire
- VinLink data sheet for the incident 2005 Toyota Prius
- Expert AutoStats data sheets for a 2005 Toyota Prius
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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[6] Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

1. Identify the biomechanical failures that Mr. Irons claims were caused by the subject incident on January 25, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1998 Pontiac Sunfire;
3. Determine Mr. Irons's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Irons' personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records indicate Mr. Irons attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
  - C5-6 broad based disc osteophyte with a right sided protrusion
  - C6-7 minor disc bulging more to the right and a small right foraminal protrusion
- Thoracic and Lumbar Spine
  - Sprain/strain

[7] Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

[8] King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering, 2*(1), 55-81.

[9] King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering, 3*(1), 27-55.

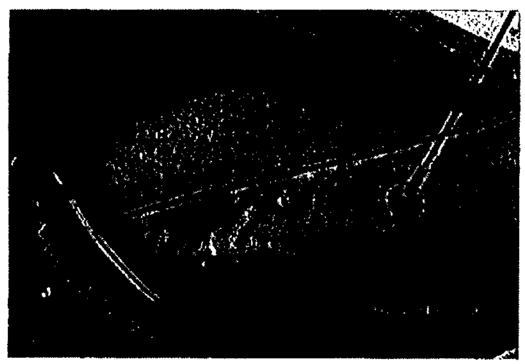
[10] Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

- Right Shoulder
  - Suspected SLAP tear at the level of the biceps anchor
  - Moderately small nearly full thickness articular surface tear of the distal supraspinatus tendon involving up to 80% of the normal width
  - Chondromalacia, Grade 3-4, of the undersurface of the patella and trochlear groove
  - Moderate subacromial/subdeltoid bursitis

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 1998 Pontiac Sunfire and the incident 2005 Toyota Prius in association with accepted scientific methodologies.[11,12]

The Estimate of Record for the subject Pontiac reported damage primarily to the rear bumper assembly, left and right tail lamps, and trunk lid panel due to the subject incident. The reviewed photographs of the subject Pontiac were consistent with the repair estimate; the photographs depicted damage to the rear bumper cover, as the cover had been pulled down and away from the upper bumper cover attachments indicated by the vertical gouges in the rear bumper cover (Figure 1). Further, the photographs depicted no crush or misalignment of the trunk lid, tail lamps, and rear bumper structures. However, the photographs did indicate the contact was slightly offset toward the passenger's side rear as indicated by the scratching and scuffing along the right rear bumper cover.



[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

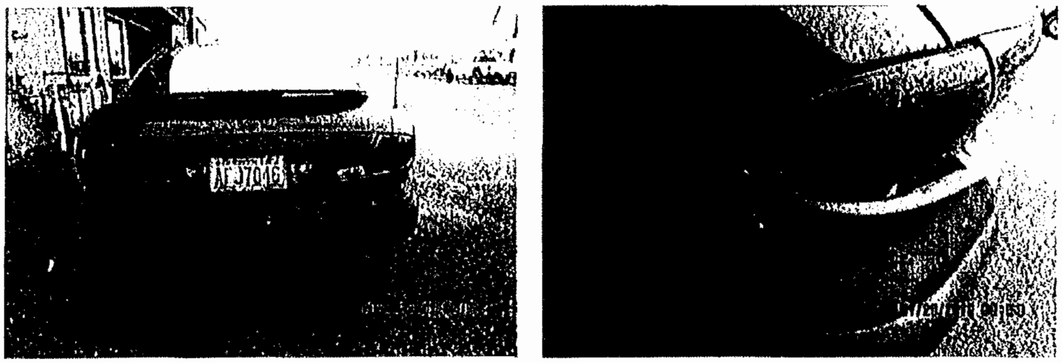


Figure 1: Reproductions of photographs of the subject 1998 Pontiac Sunfire

The Estimate of Record for the incident Toyota reported damage primarily to the front bumper cover, right splash shield, right fender, and left outer door panel (edge) (Figure 2). Further, the record reported the Toyota required a pull to the front sheet metal along with a frame set up and measure. The reviewed photographs of the incident Toyota were consistent with the repair estimate; the photographs depicted damage skewed toward the left front as indicated by the paint chipping and impression on the left front bumper cover. There was no significant crush to the front structures as the headlight, grille, and license plate bracket all appear intact. Additionally, there is good alignment of the upper structures underneath the hood with no apparent broken components as support by the repair record.

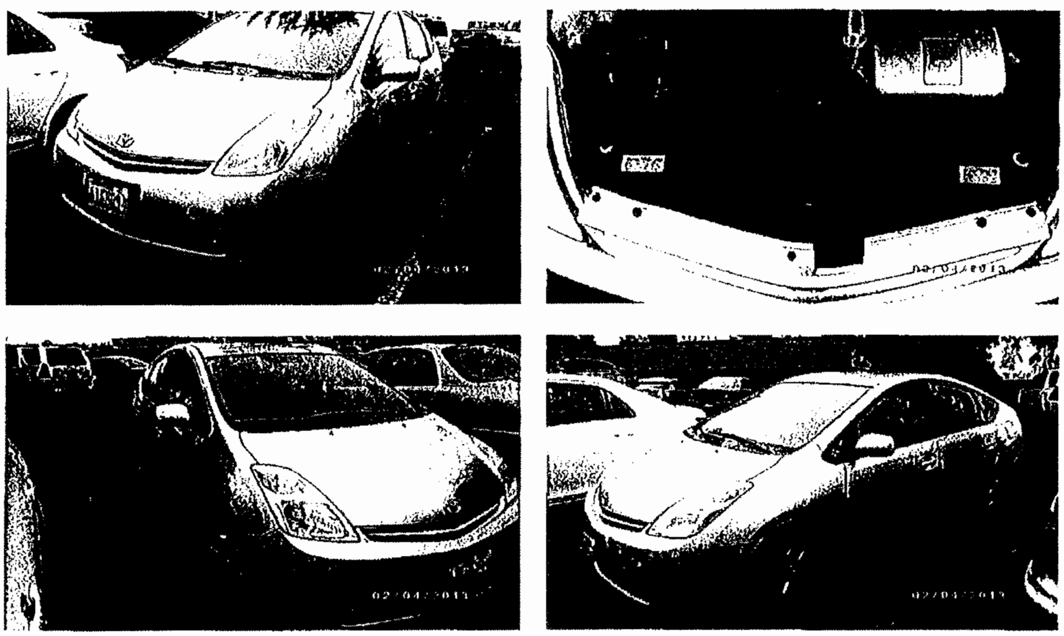


Figure 2: Reproductions of photographs of the incident 2005 Toyota Prius

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Toyota can be used to resolve the loads sustained by the subject Pontiac. That is, the loads sustained by the incident Toyota are equal and opposite to those of the subject Pontiac. Damage threshold speed change analyses along with the conservation of linear momentum have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17]

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident 2005 Toyota Prius, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis. The IIHS tested a 2008 Toyota Prius [18] in a 6.2 mile-per-hour frontal full overlap impact test. The test Prius sustained damage to the front bumper cover, front bumper reinforcement, left and right headlamp mounting brackets, hood panel, hood lock vertical support, hood latch, left and right hood hinge, radiator panel upper crossmember, radiator panel lower crossmember, radiator support panel cover, and AC condenser. The primary damage to the incident Prius was to the front bumper cover, right splash shield, right fender, left outer door panel, along with a frame setup and pull. Thus, because the test Toyota Prius in the IIHS frontal impact test sustained significantly greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed significantly below 7.6 miles-per-hour for the subject Pontiac Sunfire. The 7.6 mile-per-hour speed is based upon a conservation of momentum analysis for both vehicles.

Furthermore, another damage threshold speed change analysis was performed utilizing the IIHS test for a 1995 Chevrolet Cavalier[19], essentially the same vehicle as the subject Pontiac Sunfire. The Chevrolet Cavalier was tested in a 5 mile-per-hour rear full overlap impact into a flat barrier. The test Chevrolet Cavalier sustained damage to the rear bumper absorber and rear body panel. The primary damage to the subject Pontiac Sunfire was to the rear bumper assembly, left and right tail lamps, and trunk lid panel. Thus, because the test Chevrolet in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed consistent with 6.5 miles-per-hour for the subject Pontiac Sunfire. Additionally, Mr. Irons testified the subject Pontiac Sunfire was pushed forward "maybe a foot". Utilizing this information with a skid-to-stop analysis of the subject Pontiac results in a Delta-V consistent with the above 6.5 mph.

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13 Siegmund, G.P., et al., (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

14 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

15 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts*. (No. 950352). SAE Technical Paper.

16 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

17 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

18 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 2008 Toyota Prius, September 2008.

19 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1996 Midsize Four-Door Sedans, May 1995.

Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V consistent with 6.5 miles-per-hour for the subject Pontiac Sunfire. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.5 mile-per-hour impact is 2.0g.[20,21,22,23] By the laws of physics, the average acceleration experienced by the subject Pontiac Sunfire in which Mr. Irons was seated was less than 2.0g. Energy-based crush analyses to the rear of the subject Pontiac and front of the incident Toyota were consistent with the above analyses.[24,25,26,27,28]

The acceleration experienced due to gravity is 1g, which means that Mr. Irons experiences 1g of loading while in a sedentary state. Therefore, Mr. Irons experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[29] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Irons testified he was reading a newspaper at the time of the impact. He testified that he knows his body went forward and the seat belt kept him back. The medical records specifically noted that Mr. Irons' head was bent forward while reading the newspaper. Further, due to the impact, Mr. Irons testified his glasses came off and his hat went into the back seat. The laws of physics dictate that when contact occurred to the rear of the subject Pontiac Sunfire, the vehicle would have been pushed forward causing Mr. Irons' seat to move forward relative to his body. This rearward motion would result in Mr. Irons moving rearward relative to the interior of the subject vehicle and his body, specifically his entire torso and pelvis, would load into the seatback structures. Any rebound would have been within the range of protection afforded by the available restraint system. Mr. Irons testified he was wearing the available three point restraint at

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20 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

21 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

22 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

23 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

24 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

25 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

26 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

27 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

28 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

29 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

the time of the incident. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Irons would have been limited to well within the range of normal physiological limits.

<u>Evaluation of Biomechanical Failure Mechanisms:</u>

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Irons was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[30,31]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Cervical Spine</u>

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Pontiac would be pushed forward and Mr. Irons would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[32] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific

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30 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

31 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

32 White III, A. A. and M. M. Panjabi (1990). <u>Clinical Biomechanics of the Spine</u>. Philadelphia, J.B. Lippincott Company.

investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[33,34] Examination of an exemplar 2002 Pontiac Sunfire, production model years 1995-2005, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 29.5 inches in the full-down position and 31.0 inches in the full-up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Mr. Irons' medical records indicated he was 70 inches tall, approximately 252 lbs., and 49 years old at the time of the subject incident. Performing an anthropometric regression of Mr. Irons revealed he would have a normal seated height of 35.4 inches. Thus, the seatback and headrest would have provided Mr. Irons' head and cervical spine with support and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Furthermore, any forces applied due to interaction with the head restraint would have been applied perpendicular to the cervical spine, thereby limiting compressive loading.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[35,36,37,38,39] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[40] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[41,42,43,44] Additional

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33 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

34 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

35 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

36 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

37 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

38 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

39 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

40 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

41 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

42 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[45] Mr. Irons testified he worked as a mover which required him to move furniture, lift about 80 lbs. and operate a forklift. Further he enjoyed activities such as basketball, working out at home, and fishing.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Irons cannot be made.

Thoracic and Lumbar Spine

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. During an event such as the subject incident, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. In the absence of this acute biomechanical failure mechanism for lumbosacral disc failure, scientific investigations have shown that the above thoracic and lumbar disc diagnoses can be the result of the normal aging process.[46,47]

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[48,49,50,51] This testing has demonstrated occupants moved

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43 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

44 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

45 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper.

46 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

47 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

48 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

49 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

50 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[52] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[53,54] Mr. Irons' thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[55,56,57,58,59]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident.[60,61,62,63] Further studies lumbar accelerations during activities of daily living and found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[64,65] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with

[51] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[52] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

[53] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[54] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[55] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[56] Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[57] Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine, 7*(3), 184-191.

[58] Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics, 16*(7), 549-559.

[59] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[60] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics, 44*(8), 781-794.

[61] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics, 27*(8), 754-758.

[62] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics, 46*(3), 511-514.

[63] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

[64] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

[65] Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

physical therapy, were comparable to or greater than those associated with the subject incident.[66] Mr. Irons testified he lift up to 80 lbs. at work, moved furniture, and unloaded trucks. A segmental analysis of Mr. Irons demonstrated that as he lifted objects during daily tasks, the forces applied to his lumbar spine would have been comparable to or greater than those during the subject incident.[67,68,69]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Irons, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Right Shoulder

Biomechanical failures to the shoulder occur when an event consists of both the appropriate failure mechanism and the force magnitude to exceed the strength of these structures. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis and teres minor are the four muscles of the "rotator cuff." The supraspinatus runs laterally from the posterosuperior scapula to the head of the humerus. The supraspinatus tendon creates the connection between the supraspinatus muscle and the humeral head.[70] The biomechanical failure mechanism required to cause a supraspinatus tear involves loading through the upper arm that forcibly presses the humeral head against the acromion and coracoacromial ligament in the superior-posterior aspect of the glenoid fossa.[71,72,73] Shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. Impingement syndrome is a result of the supraspinatus becoming entrapped between the anterior head of the humerus and acromion, coracoacromial ligament, or the acromioclavicular joint.[74,75,76] An acute SLAP (superior labral anterior to posterior) tear requires loading directed into the glenoid fossa that generates a

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66 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, 29(20), 2319-2329.

67 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

68 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

69 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

70 Netter, F.H. (1989) Atlas of Human Anatomy, Ciba-Geigy Corporation

71 Giaroli, E.L., Major, N.M., et al. (2005). "MRI of Internal Impingement of the Shoulder." American Journal of Radiology 185: 925-929.

72 Weaver, J.K., (1987). "Skiing-related Injuries to the Shoulder." Clinical Orthopaedics and Related Research 216: 24-28.

73 Warner, J.J., Higgins, L., Parsons, I.M., et al., (2001). "Diagnosis and Treatment of Anteriorsuperior Rotator Cuff Tears." Journal of Shoulder and Elbow Surgery 10(1): 37-46.

74 Seeger, L.L., Gold, R.H., et al. (1988). "Shoulder Impingement Syndrome: MR Findings in 53 Shoulder." AJR, 150:343-347.

75 Murray, J-C. and Pelet, S. (2014). "Shoulder Impingement Syndrome Caused by a Voluminous Subdeltoid Lipoma." Case Reports In Orthopedics, Article ID 760219.3.

76 Escamilla, R.F., Hooks, T.R., Wilk, K.E. (2014). "Optimal management of shoulder impingement syndrome." Jounral of Sports Medicine, 2014:5 13-24.

shearing force between the humeral head and glenoid labrum.[77,78,79] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[80] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15]

Mr. Irons' torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[81,82,83,84] Mr. Irons testified he was reading the newspaper, as such his hands and arms were not directly loaded. The seatback would have distributed any loading across his entire back and shoulders. Any rebound would have been limited by the seat belt which would have engaged Mr. Irons' bony right clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Mr. Irons' right shoulder would have been limited to well within the range of normal physiological limits.

The available documents indicated that Mr. Irons performed normal activities prior to the subject incident without biomechanical failure. Specifically, Mr. Irons testified he lifted and moved boxes and furniture for his job. These activities would directly load Mr. Irons' right shoulder multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[85,86,87,88] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Mr. Irons' personal tolerance.

As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of Mr. Irons cannot be made.

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77 D'Alessandro, D.F., Fleischli, E., et al. (2000). "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.

78 Payne, L. Z., (1994). "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.

79 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008). "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.

80 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

81 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

82 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects.* (No. 2001-01-0168). SAE Technical Paper.

83 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

84 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

85 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

86 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

87 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

88 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

Personal Tolerance Values

As noted previously, according to the available documents and testimony, Mr. Irons worked as a mover. He moved furniture, objects up to 80 lbs. and worked up to 50 hours per week. In addition, Mr. Irons participated in recreational activities such as basketball, fishing and camping. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Irons and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[89]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Irons' reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Irons using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On January 25, 2013, Mr. Lonnie Irons was the seat belted right front passenger of a 1998 Pontiac Sunfire traveling westbound on Emerson Street in Fircrest, Washington when the subject Pontiac was contacted in the rear at a low speed by a 2005 Toyota Prius.
2. The severity of the subject incident was below 6.5 miles-per-hour with an average acceleration less than 2.0g.
3. The acceleration experienced by Mr. Irons was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Mr. Irons' body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Irons' claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

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89 Rudny, D.F., Sallmann, D.W. (1996). ***Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).*** (No. 960654). SAE Technical Paper.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Irons' claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

7. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Irons' claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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February 11, 2015

Stacie H. Rosenzweig, Esquire
Halling & Cayo, S.C.
320 East Buffalo Street
Suite 700
Milwaukee, WI 53202

Re: *Walsh, Daniel E., et. al. v. State Farm*
Claim No.: 49-02F5-035
File No.: 17527
ARCCA Case No.: 2251-1294

Dear Ms. Rosenzweig:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Daniel Walsh. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.
2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.
3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.
4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax, *Annual Review of Biomedical Engineering*, 2(1), 55-81.
5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the Wisconsin Motor Vehicle Accident Report and other available documents, on March 17, 2011, Mr. Daniel Walsh was the seat belted driver of a 2004 Toyota Tacoma traveling westbound along the I-94 off ramp at Redford Boulevard in Waukesha, Wisconsin. Mr. Bruce Powell was the seat belted driver of a 1995 Dodge Intrepid traveling directly behind the Toyota. The available documents indicated that as the Toyota stopped for traffic, the Dodge was unable to stop in time, resulting in contact between the front of the Dodge and the rear of the Toyota.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Wisconsin Motor Vehicle Accident Report, Police No. W11018959
- Seven (7) color photographic reproductions of the subject 2004 Toyota Tacoma
- Plaintiff's Responses to Defendants, State Farm Mutual Automobile Insurance Company's First Set of Interrogatories and Requests for Production of Documents, *Beer Capitol Distributing Co. and Beer Distributing Lake Country LLC Employee Health Care Plan v. State Farm Mutual Automobile Insurance Company* [May 20, 2014]
- Deposition Transcript of Daniel E. Walsh [December 9, 2014]
- Medical Records pertaining to Daniel Walsh
- VinLink data sheet for the subject 2004 Toyota Tacoma
- Expert AutoStats data sheets for a 2004 Toyota Tacoma
- VinLink data sheet for the incident 1995 Dodge Intrepid
- Expert AutoStats data sheets for a 1995 Dodge Intrepid
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

1. Identify the biomechanical failures that Mr. Walsh claims were caused by the subject incident on March 17, 2011;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2004 Toyota Tacoma
3. Determine Mr. Walsh's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Walsh's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Mr. Walsh attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
  - Aggravation/exacerbation of a C5-6 disc protrusion
  - Aggravation/exacerbation of multilevel disc osteophyte complexes
- Lumbar Spine
  - Aggravation/exacerbation of L3-4 mild diffuse disc bulge with superimposed small right paracentral protrusion
  - Aggravation/exacerbation of L4-5 mild diffuse disc bulge, moderate degenerative facet changes and a small midline annular tear
- Left Shoulder
  - Partial thickness tear of the biceps tendon
  - Massive rotator cuff tear retracted to the level of the glenoid. The tear encompassed the entirety of the supraspinatus and infraspinatus tendons

[8] King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.
[9] King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.
[10] Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

- Right Shoulder
  - Region of the biceps anchor showed a degenerative SLAP tear with fraying of the superior labrum
  - Full thickness tear of the supraspinatus tendon

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 2004 Toyota Tacoma in association with accepted scientific methodologies.[11,12]

The reviewed photographs depicted damage to the rear bumper; it had been pulled down and pushed forward under the left side bed panel (Figure 1). Further, the photographs depicted a missing left side step pad and a small region denting under the left rear tail light. The damage was primarily to the left rear of the subject Toyota. The Wisconsin Motor Vehicle Accident Report indicated the damage to both vehicles was minor.

Figure 1: Reproductions of photographs of the subject 2004 Toyota Tacoma

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the subject 2004 Toyota Tacoma revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile-per-hour angled flat barrier impact to the rear of a Toyota Tacoma would result in significant and visibly noticeable

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

13 Campbell, K.L. (1974). *Energy Basis for Collision Severity.* (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment.* (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3.* (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions.* (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V.* (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

crush across the entirety of the subject Toyota's rear structure, with a residual crush of 6.25 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire rear of the subject Toyota indicates that the subject incident is consistent with a collision resulting in a Delta-V below 10 miles per hour.

Furthermore, another damage threshold speed change analysis was performed utilizing the IIHS test for a 1998 Toyota Tacoma [20], essentially the same vehicle as the subject Toyota Tacoma. The Toyota Tacoma was tested in a 5 mile-per-hour rear full overlap impact into a flat barrier, resulting damage to the cab of the truck due to the bed striking it. Other damage included the rear bumper mount brackets and transmission mount. In addition, testing by Nyquist et al. subjected Hybrid III test dummies to various rear truck impacts and observed the damage along with impact accelerations. The results show the rear impacts resulting in a Delta-V of 10.3 miles-per-hour or above causes the rear window to separate from the window seal and glass fracture in some cases.[21]

Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V below 10 miles-per-hour for the subject Toyota Tacoma. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Toyota Tacoma in which Mr. Walsh was seated was less than 3.0g.

The acceleration experienced due to gravity is 1g, which means that Mr. Walsh experiences 1g of loading while in a sedentary state. Therefore, Mr. Walsh experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1998 Toyota Tacoma, May 1995.

21 Nyquist, G.W., DuPont, F.T., Patrick L.M., (1984) Pick-Up Truck Rear Window Tempered Glass as a Head Restraint – Head and Neck Loads Relative to Injury Reference Criteria, (SAE 841658). Warrendale, PA, Society of Automotive Engineers.

22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

23 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

Mr. Walsh testified that he was seated with his torso turned left and was unaware of the impending collision. He further testified that the subject vehicle was stopped and he had both hands on the steering wheel. The laws of physics dictate that when contact occurred to the rear of the subject Toyota Tacoma, the vehicle would have been pushed forward causing Mr. Walsh's seat to move forward relative to his body. This rearward motion would result in Mr. Walsh moving rearward relative to the interior of the subject vehicle and his body, specifically his entire torso and pelvis, would load into the seatback structures. Any rebound would have been within the range of protection afforded by the available restraint system. Mr. Walsh testified he was wearing the available three point restraint at the time of the incident. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Walsh would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Walsh was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota would be pushed forward and Mr. Walsh would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Damage or biomechanical failure

27 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

28 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[29] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[30,31]

Examination of an exemplar 2001 Toyota Tacoma, production model years 1995-2004, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 29.5 inches in the full-down position and 31.5 inches in the full-up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Mr. Walsh's medical records indicated he was 68 inches tall, approximately 200 lbs., and was 53 years old at the time of the subject incident. Performing an anthropometric regression of Mr. Walsh revealed he would have a normal seated height of 34.2 inches. Note, Mr. Walsh testified that the headrest on his seat was in the "up" position, however, the photographs of the subject Toyota Tacoma show the headrest in the down position. Regardless, the seatback and headrest would have provided Mr. Walsh's head and cervical spine with ample support and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Furthermore, any forces applied due to interaction with the head restraint would have been applied perpendicular to the cervical spine, thereby limiting compressive loading.

Due to Mr. Walsh's leftward turned torso at the time of the subject incident, his cervical spine may have been exposed to some lateral flexion as well as rear extension. Several researchers have conducted human volunteers lateral and rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[32,33,34,35,36,37,38,39,40,41] The test subjects

29 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

30 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

31 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

32 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

33 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

34 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

35 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

36 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Zaborowski, A.B., (1964) Human Tolerance to Lateral Impact with Lap Belt Only. (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

38 Zaborowski, A.B., (1964) Lateral Impact Studies: Lap Belt Shoulder Harness Investigations. (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[42] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Mr. Walsh testified he participated in many recreational activities such as boating, jet skiing, kayaking, snowmobiling, and motorcycle riding. Additionally, he testified he would occasionally run and use a cable weight machine. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [43,44,45,46] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[47]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Walsh cannot be made.

Lumbar Spine

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of

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39 Ewing, C., Thomas, D., et al., (1977) Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration, (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

40 Ewing, C., Thomas, D., et al., (1978) Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration, (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

41 Fugger, T.F., et al., (2002) Human Occupant Kinematics in Low Speed Side Impacts, (SAE 2002-01-0020). Warrendale, PA: Society of Automotive Engineers.

42 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

43 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

44 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

45 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

46 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

47 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living* (No. 2006-01-0247). SAE Technical Paper.

the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[48] In the absence of this acute biomechanical failure mechanism for lumbosacral disc failure, scientific investigations have shown that the above lumbar disc diagnoses can be the result of the normal aging process.[49,50]

During an event such as the subject incident, the lumbar spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the lumbar spine. Mr. Walsh testified his torso was turned to the left, however, the lumbar spine would be predominantly exposed to rearward forces with little to no lateral component. In addition, this would be further limited as Mr. Walsh stated that both hands were on the steering wheel, which would limit his initial rotation. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[51,52,53,54] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[55] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs, which measured

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48 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

49 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

50 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

51 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

52 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

53 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

54 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

55 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

spinal response to rear impact accelerations at severities greater than the subject incident.[56,57] Mr. Walsh's lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[58,59,60,61,62]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident.[63,64,65,66] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[67,68] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[69] Mr. Walsh testified he was an avid outdoorsman participating in hunting and fishing. Additionally, he testified he would perform home maintenance such as painting projects, window repair, and gutter repair. A segmental analysis of Mr. Walsh demonstrated that as he lifted objects during daily tasks, the forces applied to his lumbar spine would have been comparable to or greater than those during the subject incident.[70,71,72]

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56 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

57 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

58 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

59 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System, Lea & Febiger, Philadelphia, London.

60 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine, 7*(3), 184-191.

61 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics, 16*(7), 549-559.

62 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

63 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics, 44*(8), 781-794.

64 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics, 27*(8), 754-758.

65 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics, 46*(3), 511-514.

66 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

67 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

68 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

69 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine, 29*(20), 2319-2329.

70 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

71 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

72 Chaffin, DB, Andersson, GBJ, Martin, BJ, (1999) Occupational Biomechanics. Third Edition, Wiley-Interscience

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Walsh, a causal link between the subject incident and claimed lumbar biomechanical failures cannot be made.

Left and Right Shoulder

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." The supraspinatus runs laterally from the posterosuperior scapula to the head of the humerus. The supraspinatus tendon creates the connection between the supraspinatus muscle and the humeral head.[73] The biomechanical failure mechanism required to cause a supraspinatus tear involves loading through the upper arm that forcibly presses the humeral head against the acromion and coracoacromial ligament in the superior-posterior aspect of the glenoid fossa.[74,75,76] The infraspinatus attaches medially to the infraspinous fossa of the scapula and laterally to the middle facet of the greater tubercle of the humerus. Its main function is to externally rotate the arm and stabilize the shoulder joint. The biceps tendon runs along the anterior aspect of the upper arm and inserts into the scapula.[77] Therefore, acute tearing to the biceps tendon requires sudden force application to the biceps that exceeds physiologic limits.[78,79,80] An acute SLAP (superior labral anterior to posterior) tear requires loading directed into the glenoid fossa that generates a shearing force between the humeral head and glenoid labrum.[81,82,83] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[84] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any

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73 Netter, F.H. (1989) Atlas of Human Anatomy, Ciba-Geigy Corporation

74. Giaroli, E.L., Major, N.M., et al, (2005). "MRI of Internal Impingement of the Shoulder." American Journal of Radiology 185: 925-929.

75 Weaver, J.K., (1987): "Skiing-related Injuries to the Shoulder." Clinical Orthopaedics and Related Research 216: 24-28.

76 Warner, J.J., Higgins, L., Parsons, I.M., et al., (2001). "Diagnosis and Treatment of Anteriorsuperior Rotator Cuff Tears." Journal of Shoulder and Elbow Surgery 10(1): 37-46.

77 Bicos J., (2008). "Biomechanics and Anatomy of the Proximal Biceps Tendon." Sports Medicine and Arthroscopy Review. 16(3): 111-117.

78 Miller, K.E., and Solomon, D.J. (2008). "Paralabral Rupture of the Proximal Biceps Tendon from Light Weightlifting." Military Medicine 173 (12): 1238-1240.

79 Bain, G.I., Johnson, L.J., and Turner, P.C., (2008). "Treatment of Partial Distal Biceps Tendon Tears." Sports Medicine and Arthroscopy Review. 16(3): 154-161.

80 Friedman, D.J., Dunn, J.C., Higgins, L.D., et al., (2008). "Proximal Biceps Tendon: Injuries and Management." Sports Medicine and Arthroscopy Review. 16(3): 162-169.

81 D'Alessandro, D.F., Fleischli, E., et al. (2000). "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.

82 Payne, L. Z., (1994). "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.

83 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008). "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.

84 Moore, K.L., and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15] In addition, Mr. Walsh's medical records indicated both shoulders had a Type II acromion, downsloping with anterior spur/osteophyte, which are degenerative changes that are frequently associated with a chronic type of shoulder failure mechanism.[85,86,87]

Mr. Walsh's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[88,89,90,91] Mr. Walsh testified his torso was turned to the left and both hands were on the steering wheel. During this rearward motion Mr. Walsh's arms and shoulder would have been unloaded from the steering wheel. The seatback would have distributed any loading across his entire back and shoulders. Any rebound would have been limited by the seat belt, which would have engaged Mr. Walsh's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Mr. Walsh's shoulders would have been limited to well within the range of normal physiological limits.

The available documents indicated that Mr. Walsh performed normal activities prior to the subject incident without biomechanical failure. Specifically, Mr. Walsh testified he was an avid outdoorsman participating in compound bow hunting, hunting with a gun, and fishing. Further, he testified he rode a snowmobile, kayaked, and jet skied. These activities would directly load Mr. Walsh's shoulders multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[92,93,94,95] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Mr. Walsh's personal tolerance.

As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported shoulder biomechanical failures of Mr. Walsh cannot be made.

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85 Ozaki, et al. (1988). Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. A study in cadavera. The Journal of Bone and Joint Surgery, 70 (8), 1224-1230

86 Whiting, W. C. and Zernicke, R.F. (2008). Biomechanics of musculoskeletal injury, Human Kinetics, Champaign, IL.

87 Burkhead, W.Z. (1996). Rotator cuff disorders. Williams & Wilkins, Baltimore.

88 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

89 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

90 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

91 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.

92 Ni Westerhoff, P., Graichen, F., Bender, A., et al. (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

93 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

94 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

95 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics, 40: 2139-2149.

Personal Tolerance Values

According to the available documents and testimony, Mr. Walsh worked as an inventory and quality control analyst for a beer distributor. This required him to repeatedly lift cases of beer along with some climbing on racks. Further, recreationally he participated in activities such as hunting, fishing, jet skiing, and motorcycle riding. Mr. Walsh testified he performed home repairs and exercised with a cable weight machine. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Walsh and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[96]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Walsh's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Walsh using peer-reviewed and generally-accepted methodologies. (1) (2) (3) (4)

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 17, 2011, Mr. Daniel Walsh was the seat belted driver of a 2004 Toyota Tacoma traveling westbound on I-94 off ramp at Redford Boulevard in Waukesha, Wisconsin when the subject Toyota was contacted in the rear at a low speed by a 1995 Dodge Intrepid.
2. The severity of the subject incident was below 10 miles-per-hour with an average acceleration less than 3.0g.
3. The acceleration experienced by Mr. Walsh was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move the Mr. Walsh's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Walsh's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

[96] Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).* (No. 960654). SAE Technical Paper.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Walsh's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

7. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Walsh's claimed bilateral shoulder biomechanical failures. As such, a causal relationship between the subject incident and the bilateral shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
Probst 38
5-23-17

February 19, 2015

Elizabeth Smith, Esquire
Law Offices of Kenneth R. Scearce
1501 4th Avenue
Suite 1130
Seattle, WA 98101

Re: *Rollins, Stephanie v. Crown Distributing, LLC, Darren Lian, Kyle Fitzhugh, Shannon Ottow & Lidia Barerra*
Claim No.: EGF2182 (WFS)
ARCCA Case No.: 2240-257

Dear Ms. Smith:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Stephanie Rollins. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the State of Washington Police Traffic Collision Report, testimony, and other available documents, on December 1, 2010, Ms. Stephanie Rollins was the seat belted driver of a 1988 Toyota Pickup traveling on northbound Highway 92 near 84th Street NE in Granite Falls, Washington. Mr. Kyle Fitzhugh was the driver of a 1995 Acura Integra traveling on southbound Highway 92 near 84th Street NE. Mr. Darren Lian was the driver of a 2004 Chevrolet Astro Van traveling directly in front of the Toyota. According to the available documents, contacted occurred between the incident Acura and the incident Chevrolet. As a result, the incident Acura spun and contact occurred between the rear of the incident Acura and the rear driver's side of the subject Toyota.

Ms. Rollins was involved in a second collision on February 15, 2012 in which the front of her 1988 Toyota Pickup contacted the side of a 2005 Chevrolet Venture. The severity of both incidents will be evaluated within this report.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 2872156
- State of Washington Uniform Incident Report, Report No. SO 10-22530
- State of Washington Police Traffic Collision Report, Report No. 2387113
- Seventeen (17) color photographic reproductions of the subject 1988 Toyota Pickup from the subject incident dated December 1, 2010
- Five (5) grayscale photographic reproductions of the subject 1988 Toyota Pickup from the subject incident dated February 15, 2012
- Thirty-three (33) color photographic reproductions of the incident 1995 Acura Integra
- Sixty-three (63) color photographic reproductions of the incident 2004 Chevrolet Astro Van
- Eleven (11) color photographic reproductions of the incident scene
- Travelers Estimate of Record for the subject 1988 Toyota Pickup [January 26, 2011]
- Travelers Estimate of Record for the incident 1995 Acura Integra [December 15, 2010]
- Travelers Estimate of Record for the incident 2004 Chevrolet Astro Van [December 3, 2010]
- Recorded Statement Transcript of Stephanie Rollins [January 25, 2011]

- Defendants Ottow's First Set of Interrogatories and Requests for Production to Plaintiff, *Stephanie Rollins v. Crown Distributing, LLC, Darren Lian, Kyle Fitzhugh, Shannon Ottow & Lidia Barerra* [March 13, 2014]
- Declaration of James Alberts, MD, *Stephanie Rollins v. Crown Distributing, LLC, Darren Lian, Kyle Fitzhugh, Shannon Ottow & Lidia Barerra* [December 2, 2013]
- Plaintiff's First Requests for Admission to Defendant Crown Distributing Company of Everett, Inc., *Stephanie Rollins v. Crown Distributing, LLC, Crown Distributing Company of Everett, Inc., Crown Distributing Company of Aberdeen, Darren Lian, Kyle Fitzhugh, Shannon Ottow & Lidia Barerra* [December 19, 2013]
- Deposition Transcript of Stephanie Rollins [September 3, 2014]
- Medical Records pertaining to Stephanie Rollins
- VinLink data sheet for the subject 1988 Toyota Pickup
- Expert AutoStats data sheets for a 1988 Toyota Pickup
- VinLink data sheet for the incident 1995 Acura Integra
- Expert AutoStats data sheets for a 1995 Acura Integra
- VinLink data sheet for the incident 2004 Chevrolet Astro Van
- Expert AutoStats data sheets for a 2004 Chevrolet Astro Van

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Rollins claims were caused by the subject incident on December 1, 2010;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Rollins was occupying during the December 1, 2010 and February 15, 2012 incidents;
3. Determine Ms. Rollins's kinematic response within the vehicle as a result of the subject incident;

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Rollins's response to the subject incident.
5. Evaluate Ms. Rollins's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Rollins attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
  - L4-5 small central posterior intervertebral disc protrusion

Damage and Incident Severity, December 1, 2010:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1988 Toyota Pickup and incident 1995 Acura Integra in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject Toyota indicated damage primarily to the left rear tire, left and right leaf spring, left bedside flare, and left rear wheel. Additionally, the repair record indicated the Toyota required a four wheel alignment and alignment of the rear axle. Specifically, the photographs did not depict significant crush or misalignment to any structures (Figure 1). There was minor paint transfer on the broken left rear wheel flare and a portion of the incident Acura Integra's rear bumper cover is visible within the bead of the left rear wheel on the subject Toyota. Ms. Rollins testified the damage to the Toyota consisted of dents and scratches and a plastic piece of the incident Acura about 2-3 feet in diameter was embedded into the rear wheel. In Ms. Rollins' recorded statement, she stated the fender flare was cracked, the rear rim/tire was damaged, along with rear end and under carriage damage.

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11 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

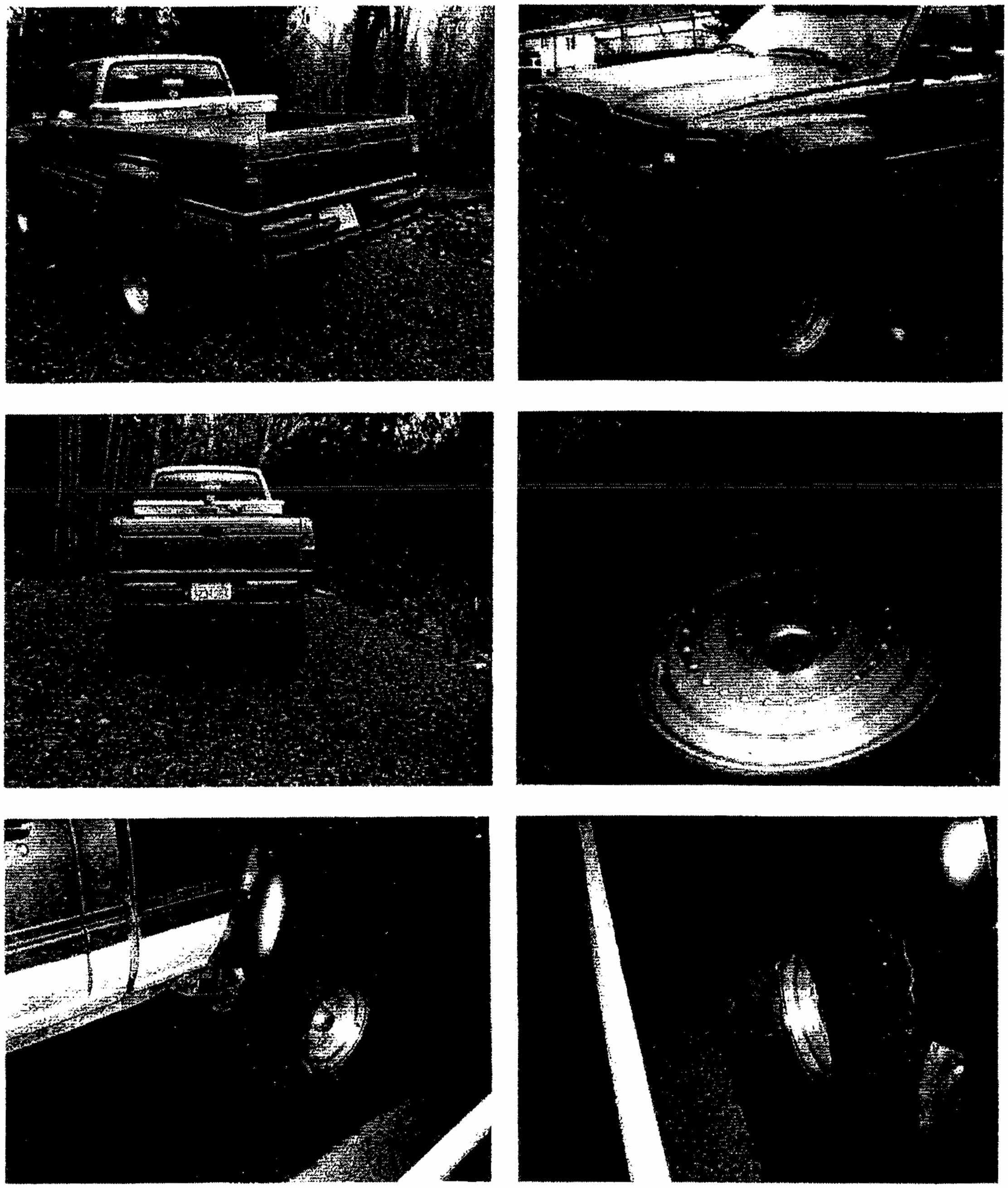

Figure 1: Reproductions of the subject 1988 Toyota Pickup

The repair estimate for the incident Acura indicated damage primarily to the rear bumper assembly, right tail lamp assembly, left quarter panel, tire, right quarter panel, lower trim, left outer panel, lift gate, left rear wheel, floor, rear body panel, skirt, and left trailing arm. Additionally, the repair record indicated the Acura required a setup, measure, and pull to the unibody/rear body. Note, the damage to the incident Acura is due to contact with the subject Toyota and the incident Chevrolet. The primary contact point on the incident Acura with the

subject Toyota would have been the right rear of the Acura. The reviewed photographic reproductions of the incident Acura depicted a broken/torn rear bumper cover, a dent in the right portion of the rear hatch, and several dark colored scuff marks (Figure 2).

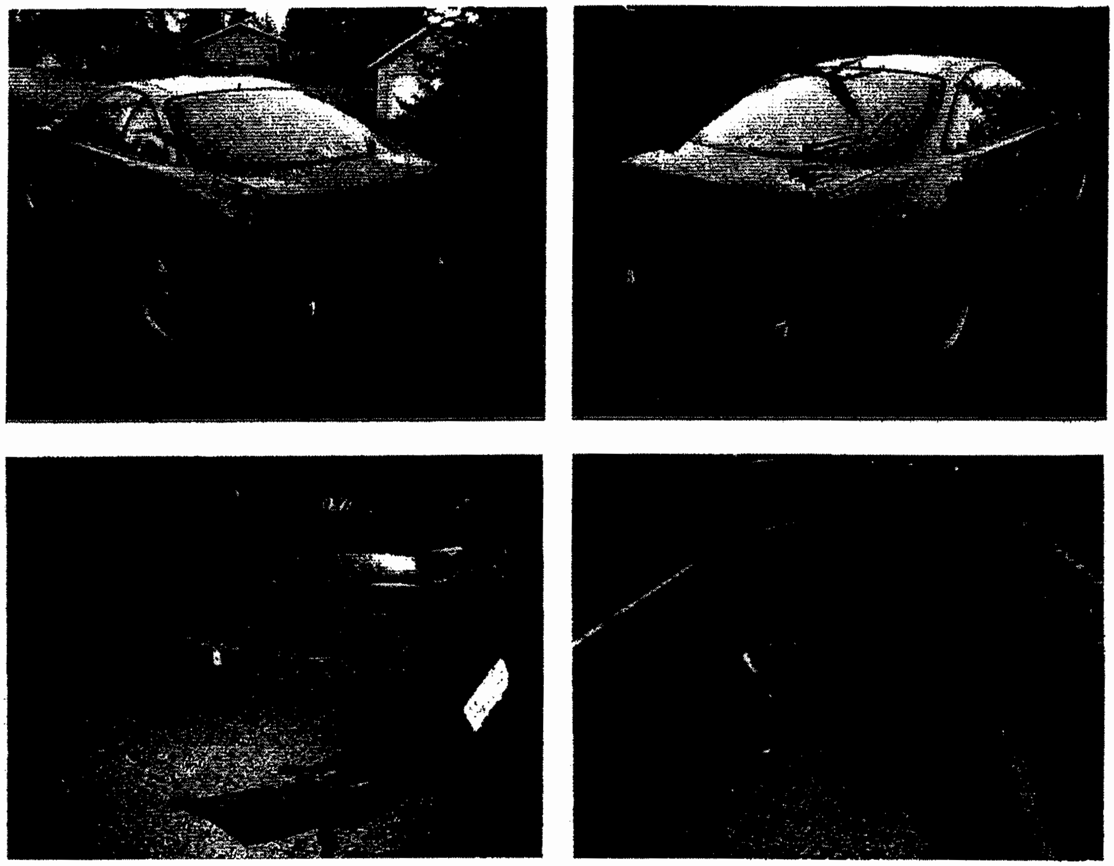

Figure 2: Reproductions of the incident 1995 Acura Integra

Scientific analyses of the photographs, itemized repair records, and geometric measurements of the vehicles, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[13] The laws of physics dictate that the longitudinal force exerted to the subject Toyota was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the subject Toyota as a result of the sideswipe event was less than 1.5g.[14] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[15] the Delta-V associated with the subject incident is 3.2 mph. Therefore, the subject Toyota Pickup in which Ms. Rollins was seated during the sideswipe event on December 1, 2010 was exposed to a Delta-

[13] Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[14] Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

[15] Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

V of less than 3.2 mph with peak acceleration less than 1.5g. The lateral forces associated with the subject incident were calculated to be insignificant. This analysis is validated by and consistent with empirical studies of axle shaft fracture and tire bead unseating.[16,17,18,19] Further, the analyses are consistent with energy-based crush analyses to the rear of the incident Acura Integra.[20,21,22,23,24]

Damage and Incident Severity, February 15, 2012:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1988 Toyota Pickup in association with accepted scientific methodologies.[25,26]

The reviewed photographs of the subject Toyota depicted damage to the front brush guard, left and right fenders, grille, left headlight and left front suspension components (Figure 1). The photographs also depict misalignment of the cab on the frame of the vehicle. Ms. Rollins testified that compared to the 2010 incident there was more damage, including the hood being pushed up and fluids leaking. Specifically, she described the second accident as *"much more forceful"*.

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[16] Bailey, M. N., B. C. Wong, et al. (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[17] Tanner, C.B., Wiechel, J.F., Guenther, D.A. (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

[18] Rucoba, R., Carr, L. , Liebbe III, R., (2005). Analysis of Axle Shaft Failures for Use in Crash Reconstruction. (SAE 2005-01-1193). Warrendale, PA, Society of Automotive Engineers.

[19] National Highway Traffic Safety Administartion (2013). "Laboratory Tire Bead Unseating - Evaluation of new Equipment, Pressures and "A" Dimension From ASTM F-2663-06as, April 2013.

[20] Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

[21] Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

[22] Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

[23] Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

[24] Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

[25] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[26] Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

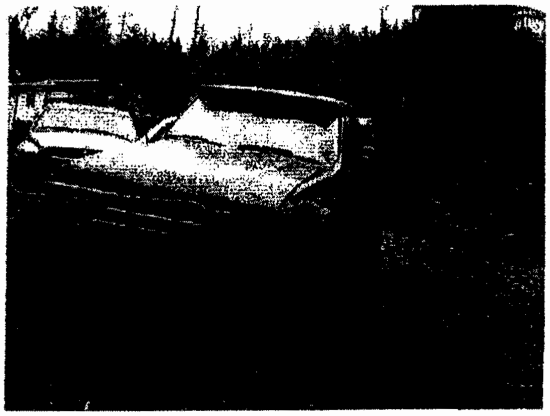

Figure 3: Reproductions of the subject 1988 Toyota Pickup

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions. [27,28,29,30,31] Analyses of the photographs, repair estimates and geometric measurements of the subject 1988 Toyota Pickup revealed the damage due to the subject incident. An energy crush analysis[32] indicates that a single 12 mile per hour angled barrier impact to the front of a Toyota Pickup would result in significant and visibly noticeable crush across the entirety of the subject Toyota's front structure, with a residual crush of 8 inches along the left front. Therefore, the energy crush analysis shows deformation consistent with the subject damage which would occur in a 12 mile per hour Delta-V impact (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).[33] The structural crush to the entire front of the subject Toyota indicates that the subject incident is consistent with a collision resulting in a Delta-V of 12 miles per hour.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V of 12 miles-per-hour for the subject Toyota Pickup. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average and peak acceleration associated with a 12 mile-per-hour impact is 3.6g and 7.3g, respectively. [34,35,36,37] By the laws of physics, the peak acceleration

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27 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

28 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

29 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

30 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

31 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

32 EDCRASH, Engineering Dynamics Corp.

33 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

34 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

35 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

36 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

37 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

experienced by the subject Toyota in which Ms. Rollins was seated on February 15, 2012 was 7.3g.

Damage and Incident Severity Discussion:

1. The subject Toyota Pickup in which Ms. Rollins was seated during the sideswipe event on December 1, 2010 was exposed to a Delta-V of less than 3.2 mph with peak acceleration less than 1.5g.
2. The subject Toyota Pickup in which Ms. Rollins was seated during the frontal impact event on February 15, 2012 was exposed to a Delta-V consistent with 12 mph with a peak acceleration consistent with 7.3g.

The acceleration experienced due to gravity is 1g. This means that Ms. Rollins experiences 1g of loading while in a sedentary state. Any motion or lifting of objects by Ms. Rollins in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[38] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

According to the available medical records, Ms. Rollins was 20 years old, 62 inches tall, and weighed approximately 147 lbs. The records continued to describe Ms. Rollins was wearing the available three point restraint.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Toyota to decelerate longitudinally and accelerate rightward. Scientific literature indicates that provided the low accelerations of the event, less than 1.5g, no significant occupant motion would have occurred.[39,40] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events, less than or comparable to 1.5g. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[41,42] dictate that Ms. Rollins would have tended to move forward and leftward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at her seat bottom, the interior driver's side

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38 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

39 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

40 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

41 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

42 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

door components, and the three point restraint.[43] Provided the low accelerations of the subject incident, and the supports described, the bodily response of Ms. Rollins would have been limited to well within normal physiological limits

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Rollins was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[44,45]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. As described previously, the sideswipe event would have caused the subject Toyota to deceleration longitudinally and accelerate to the right. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, less than 1.5g, no significant occupant motion would have occurred.[46,47] If occupant motion were assumed, Ms. Rollins would have moved forward

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[43] Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

[44] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[45] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

[46] Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

[47] Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

and leftward relative to the vehicle's interior.[48,49] This motion would have been supported and constrained by the three-point restraint, driver's side door interior components, and seat bottom friction of the subject Toyota. Ms. Rollins's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[50] As a result, Ms. Rollins' cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[51]

Many research studies support these above conclusions. Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[52,53,54,55,56,57,58,59,60,61,62] Participants moved toward the point of impact while their response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[63,64] These results demonstrated that the accelerations during the subject incident were maintained well within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal

48 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

49 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

50 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

51 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

52 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

53 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

54 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

55 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

56 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

57 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

58 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

59 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

60 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

61 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

62 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

63 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

64 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

and lateral impact accelerations.[65] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

The available documents and testimony reported Ms. Rollins worked at a day care which required her to lift children, prepare meals, and play. The records further reported that she regularly hunted, played softball, wake-boarded, and rode recreational vehicles. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[66,67] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[68] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Rollins cannot be made.

Thoracic and Lumbar Spine

In this type of collision, the motion of Ms. Rollins' thoracic and lumbar spine would have been well supported and constrained. Again, scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, less than 1.5g, no significant occupant motion would have occurred.[69,70] Provided sufficient energy to overcome Ms. Rollins's muscle reaction forces, her body would have moved forward and leftward relative to the Toyota's interior. As described previously, the available documents reported Ms. Rollins was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[71] Additionally, the driver's side door interior components would have limited Ms. Rollins's lateral movement. Therefore, Ms. Rollins' thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Ms. Rollins'

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65 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

66 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

67 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

68 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

69 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

70 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

71 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Researchers have frequently exposed human volunteers to both frontal and lateral impact accelerations at levels comparable to and greater than that of the subject incident.[72,73,74,75,76,77,78,79] No thoracic or lumbar biomechanical failures were reported. Additionally, occupant kinematics were inconsistent with the biomechanical failure mechanism responsible for the thoracic and lumbar failures. Published guidelines for safe human exposure to frontal and lateral impacts are consistent with the results from these studies.[80] These data provide support for the conclusions described previously regarding Ms. Rollins' response to the subject incident. In addition, these data demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

The subject incident had a peak acceleration below 1.5g. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[81] ARCCA has investigated the compressive lumbar force in a 50th Percentile Hybrid III when plopped into a chair, which is consistent with the previous studies. When dropped from a height of approximately 3 and 10 inches, the compressive force on the lumbar spine equated to an acceleration of approximately 1.6g to 4.7g, respectively. In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[82] Studies by Rohlmann et al.[83,84,85] have shown that seemingly benign tasks such as flexion of the upper

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72 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

73 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

74 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

75 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

76 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

77 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

78 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

79 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

80 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

81 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

82 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

83 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

84 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

85 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable or greater than those resulting from subject incident. Again, Ms. Rollins participated in hunting, wakeboarding, lifting children, riding recreational vehicles, and playing with children. These exercises would load her body to comparable or greater loads than experienced during the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Rollins, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, Ms. Rollins worked full-time at a day care. Ms. Rollins lifted children and played with children, among other activities. Further, she participated in many recreational activities including softball and hunting. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Rollins and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[86]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Rollins' reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Rollins using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On December 1, 2010, Ms. Stephanie Rollins was the seat belted driver of a 1998 Toyota Pickup that was contacted in the rear driver's side at low speed by a 1995 Acura Integra.

[86] Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

2. The severity of the subject incident was consistent with a Delta-V less than 3.2 miles-per-hour with peak a acceleration less than 1.5g for the subject 1998 Toyota Pickup in which Ms. Rollins was seated.
3. The acceleration experienced by Ms. Rollins was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Ms. Rollins' body would have moved forward and leftward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint, driver's side door interior components, and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Rollins's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Rollins' claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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Mary F. O'Boyle, Of Counsel

March 5, 2015

Anthony C. Otto
Attorney at Law
P.O. Box 1368
Port Orchard, WA 98366

Re: Quinn v. Ronkar

Dear Mr. Otto:

Enclosed please find our expert report from Mr. Probst. Please allow this letter to supplement all applicable discovery responses and disclosures as they pertain to expert witnesses

Sincerely,

Sent Without Signature To Avoid Delay

Joseph R. Kopta

Jmf
Enclosures

FILE COPY
copy to client 3/9/15
by X mail / personal delivery